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TWENTY-FOURTH ANNUAL REPORT OF THE POWER AFFILIATES PROGRAM

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TABLE OF CONTENTS

FOREWORD

This report provides a summary of the activities of the Power Affiliates Program (PAP) in the Department of Electrical and Computer engineering at the University of Illinois for the calendar year 2002. The information is intended to be a progress report to the affiliate companies listed below. The PAP is the foundation of the industrial liaison effort in the power and energy systems area. There are eleven active affiliates associated with the PAP. They are:

Alliant Energy
Ameren Services
BP America
Central Illinois Light Company
City Water, Light & Power
Electrical Manufacturing & Coil Winding Association, Inc.
Exelon
MidAmerican Energy
PowerWorld Corporation
S&C Electric Company
Sargent & Lundy Engineers

2002 was an active year for the PAP and the highlights are covered in this report. We acknowledge the valuable support of the Affiliates and are most thankful to these companies for their continued support.

Pete Sauer, Director
Patrick Chapman
George Gross
Stan Helm
Jonathan Kimball
Phil Krein
Tom Overbye
M. A. Pai

1. INTRODUCTION AND SUMMARY

The Power Affiliates Program (PAP) was initiated in January 1979 as part of a major effort to strengthen the power and energy systems area. The original objectives were to

- Maintain stimulating, meaningful and high quality undergraduate and graduate programs in electric power engineering
- Increase university-industrial interaction at all levels of education and research in electric power engineering.

These objectives are as much valid today as they were in 1979. The multi-faceted activities in 2002 under the PAP umbrella clearly were in support of these objectives.

Throughout the past twenty-three years, the Power Affiliates Program has maintained a stable base during times of rapid change. This base provided the seed money for research, which led to additional funding by other sources. This base has also made it possible for students to be exposed to industrial problems and to participate in technical and professional meetings. With the cyclical nature of funding by government agencies, the Power Affiliates Program is a critically important source of support.

This annual report is organized as follows. A financial statement for the calendar year 2002 is given in Section 2. Section 3 describes how the power program fits into the departmental structure. There is no official degree or option associated with the Power Program, but there is a significant level of specialization which is possible in this area through a set of courses developed and offered by the group of faculty who constitute the Power and Energy Systems Area. Section 4 gives a brief description of the courses for specializing in electric power and tabulates the enrollment figures for the most recent offerings. Included in this section is an historical record of the number of graduates who have taken three or more of these courses. Section 5 lists the activities of both the students and the faculty members during the 2002 calendar year. Section 6 provides a brief summary of research projects that are funded by various sources. Section 7 gives information about the graduate students in the power area. In addition to personal data and interests, each student has written a brief abstract of his or her research work. Laboratories and other facilities of the power area are discussed in Section 8. The report concludes with a directory in Section 9 and list of publications in Section 10.

2. FINANCIAL STATEMENT

The following tabulation of income and expenditures for the calendar year 2002 was prepared from a detailed University statement as of December 31, 2002, Reference [1].

Income carried over from the calendar year 2001	$ 36,758
Total income during calendar year 2002	57,000
Total available income during calendar year 2002	$93,758

Expenditure	**Expenditure Amount**
Personnel and Services	$21,657
Materials/Supplies/Equipment	3,630
Transportation/Travel	2,323
Total expenditures	$27,610

Summary

Amount of funds available during calendar year 2002	$93,758
Amount of expenses during calendar year 2002	27,610
Balance as of December 31, 2002	$66,148

3. THE POWER PROGRAM WITHIN THE DEPARTMENT

Electrical engineering undergraduate students are required to complete 128 hours of course work for a B.S.E.E. degree. Detailed descriptions of the undergraduate program and suggested curriculum in Power are given in Reference [2]. All M.S.E.E. students are required to complete a minimum of 8 units (32 credit hours) including a graduate thesis. All Ph.D. students must qualify through a written examination and complete course and thesis requirements. A detailed description of the graduate program is given in Reference [3].

The Electrical and Computer Engineering Department is subdivided into eight distinct technical areas as follows:

Bioengineering and Acoustics
Circuits and Signal Processing
Communication and Control
Computational Science and Engineering
Computer Engineering
Electromagnetics, Optics and Remote Sensing
Microelectronics and Quantum Electronics
Power and Energy Systems

While the Department does not have official degree-granting options in each of these areas, in practice, the eight areas serve as the appropriate grouping of the faculty activities and interest. In terms of size, the Power and Energy Systems area represents about 8% of the total active faculty and about 10% of the total student enrollment. The faculty committee in each area has the responsibility for administering courses and research in that area within the Department.

The Power and Energy Systems Area Committee and associated faculty for the 2002 - 2003 academic year together with their general interests are:

P. Chapman	(machines, power electronics, circuits)
G. Gross	(power system economics, planning and operations; electric regulatory policy; industry restructuring; competitive market mechanisms)
M. S. Helm, Emeritus	(power system analysis)
P. T. Krein	(power electronics, machines, electrostatics)
T. J. Overbye	(dynamics, stability and operations of power systems)
M. A. Pai	(dynamics, stability and computational methods in power systems
P. W. Sauer	(modeling and simulation of machines and power systems)

Two of the primary responsibilities of the Power and Energy Systems Area Committee are to improve, keep current and staff the courses assigned to the Power and Energy Systems Area. In 2000-2003 those courses were

ECE 271GG	Engineering Decision Techniques
ECE 330	Power Circuits and Electromechanics
ECE 333	Electric Machinery (with laboratory)
ECE 336	Advanced Electromechanical Energy Conversion
ECE 364	Power Electronics
ECE 369	Power Electronics Laboratory
ECE 371AHV	Advanced Hybrid Automotive Systems
ECE 371FEC	Future Energy Challenge
ECE 371HEV	Hybrid and Electric Automotive Systems
ECE 376	Power System Analysis I
ECE 378	Power System Analysis II
ECE 468	Modeling and Control of Electromechanical Systems
ECE 473	Operation and Control of Power Systems
ECE 476	Dynamics and Stability of Power Systems
ECE 488	Electricity Resource Planning
ECE 490I	Power and Energy Systems Area Seminar
ECE 497PE	Power Electronic Drives and Systems
ECE 497PH	Hybrid Systems Analysis of Power System Dynamics
ECE 497PS	Power System Modeling and Analysis
ECE 497TO	Issues in Competitive Electricity Markets

The three hundred level courses are advanced undergraduate or beginning graduate courses, while the four hundred level courses are graduate. Of these courses, ECE 271GG, ECE 336, ECE 371AHV, ECE 371HEV, ECE 468, ECE 497PE, ECE 497PH, ECE 497PS, and ECE 497TO were not taught during the 2002-2003 academic year. The Power and Energy Systems Area Committee periodically evaluates each course outline for possible revision for future offerings. A brief description of each of these courses, together with the enrollment of the past year, is included in the next section. In addition, power area faculty members are active in ECE 345, Design Projects. This is the capstone design course for our seniors.

4. COURSES AND ENROLLMENT

As one of eight major areas in Electrical and Computer Engineering, the Power and Energy Systems Area is responsible for the development and offering of a considerable number of courses. The current courses assigned to the power area are described briefly below. The total enrollment for courses offered in the academic year 2002-2003 is also given for each course.

ECE 271GG Engineering Decision Techniques

This course is concerned with modeling of decisions and analysis of models to develop a systematic approach to making decisions. The focus is on the development of techniques for solving typical problems faced in making engineering decisions in industry and government. Topics include resource allocation, logistics, scheduling, sequential decision-making and explicit consideration of uncertainty in decisions. Extensive use of case studies gets students involved in real world decisions. The course has two required texts: Operations Research: Principles and Practice, A. Ravindran, D. T. Phillips and S. S. Solberg and Making Hard Decisions: An Introduction to Decision Analysis, R. T. Clemen. This course was not offered during the academic year 2002-2003.

ECE 330 Power Circuits and Electromechanics

ECE 330 is a course in power circuits and electromechanics. It is a new course after the restructuring of the undergraduate curriculum. The course starts with a review of phasors followed by three phase power circuits, mutual inductance, magnetic circuits and transformers. Electromechanical systems are analyzed using energy balance concepts. Introduction to synchronous, induction, dc and small machines is given. The required text was Power Circuits and Electromechanics by M.A. Pai. The total enrollment for the academic year 2002-2003 was 252.

ECE 333 Electric Machinery

This four-hour course contains a laboratory one credit hour component, which is an elective in a list of 14 from which students select two. The fifteen experiments typically include power measurement, power factor correction, transformer characteristics, three-phase transformer connections, induction motor tests, induction motor torque-speed characteristics, synchronous machine tests, synchronous machine power characteristics, digital simulation of machine dynamics, motor control, and a written plus oral project presentation on power and energy system topics. The required text was Electric Machinery Fundamentals, 3rd edition, by S. J. Chapman. The total enrollment for the academic year 2002-2003 was 36.

ECE 336 Advanced Electromechanical Energy Conversion

This three-hour course contains advanced theory and analysis of rotating and linear machines and drives. It includes power electronic drives for dc and ac motors. The analysis uses d-q transformations and related techniques. Emphasis is placed on the time scale modeling of electromechanical devices and on their function in drives. The required text was Analysis of Electric Machinery, by P.C. Krause and O. Wasynczuk, IEEE Press. This course was not offered during the academic year 2002-2003.

ECE 364 Power Electronics

This three-hour course is a comprehensive treatment of switching power conversion systems and the devices used to build them. Concepts of switch control are developed from general switching functions. Phase control, pulse width modulation, and phase modulation are studied for applications in all types of converters. Converter topologies are introduced along with design concepts for power filters and interfaces. Devices such as diodes, thyristors, bipolar transistors, field effect transistors, capacitors, and magnetic components are examined in the context of high-power switching applications. The required text was Elements of Power Electronics by P. T. Krein. The total enrollment for the academic year 2002-2003 was 35. The course is also available by web-based education.

ECE 369 Power Electronics Laboratory

This two-hour course is a laboratory study of circuits and devices used for switching power converters, solid-state motor drives, and power controllers, including dc-dc, ac-dc, and dc-ac converters and applications. It includes high-power measurements for silicon-controlled rectifiers, diodes, capacitors, power transistors and magnetic components. The course is designed to accompany ECE 364. A lab manual by P. Krein is used for the course. The total enrollment for the academic year 2002-2003 was 20.

ECE 371AHV/ME 393AHV Advanced Hybrid and Automotive Systems

Design, operation, and systems issues associated with automobiles that combine a combustion engine with an electrical system. Major sub-systems including engine and emission controls, inverters and electric machines, batteries and energy management, dynamic operation, and structural considerations. In this course, students are expected to build and operate working subsystems. There

is emphasis on testing, data analysis, and modifications to achieve defined engineering objectives. Laboratory work involves parametric studies and experiments with vehicle sub-systems and complete vehicles. This course was not offered during the academic year 2002-2003.

ECE 371FEC Future Energy Challenge

This three-hour course is a special topics course focusing on the 2003 Future Energy Challenge (FEC) student team competition. This competition is an international event sponsored by IEEE, the U.S. Department of Energy, the U.S. Department of Defense, and other sponsors. Schools compete in two topic areas: a fuel-cell power processing topic and a motor system topic. Illinois is one of just 7 schools selected, based on our proposal, to be part of the motor topic competition. The final events are in May after graduation. A prize of at least $25,000 will be awarded to the winning team. The total enrollment for the academic year 2002-2003 was 8.

ECE 371HEV/ME 393DRW Hybrid and Electric Automotive Systems

This four-hour course is a large-team design program directed at advanced vehicle technology and automotive electronics. A multidisciplinary team addresses all the design, implementation, and operating issues for a high-performance practical hybrid automobile. Students learn about physical and engineering considerations in battery systems, electric traction, engines, emission controls, and other automotive system issues. This course was not offered during the academic year 2002-2003.

ECE 376 Power System Analysis I

This three-hour course is the first of two courses on power system analysis. Topics included are transmission line parameter calculations, equivalent circuits, network analysis, load flow, fault analysis, symmetrical components, unsymmetrical fault analysis, and introduction to economic dispatch. The course is designed to be a stand-alone introduction to the fundamentals of power system analysis and provide the basis for all subsequent courses in the power system analysis. The required text was Power System Analysis, 2nd edition, by Bergen and Vittal. The total enrollment for the academic year 2002-2003 was 42. This course is also available by web-based education.

ECE 378 Power System Analysis II

This three-hour course is the second of two courses on power system analysis. Topics included are economic operation of power systems, optimal load flow concepts, automatic generation control, state estimation, classical transient stability, modeling for dynamic and transient stability, and d-c transmission. The recommended text is Power Generation, Operation and Control, 2nd edition, by Wood and Wollenberg. The total enrollment for the academic year 2002-2003 was 23.

Graduate Courses:

ECE 468 Advanced Modeling and Control of Electromechanical Systems

This course addresses issues of electrical drives in a modern control and circuit framework. Dynamic models of electric machines are presented. There is special emphasis on field-oriented control methods for ac motors. Power electronic systems for high-performance drives are studied. Nonlinear system methods such as periodic transformations, averaging, geometric control, and feedback linearization are presented. Special topics covered include electrostatic micromachines and permanent magnet machines. The required texts were Control of Electrical Drives, 2nd edition by W. Leonard and Analysis of Electric Machines, 2nd edition by P. Krause, O. Wasynczuk and S. Sudhoff. The course has been produced on videotape. This course was not offered during the academic year 2002-2003.

ECE 473 Operation and Control of Power Systems

The course includes energy control center functions, power system operating states, supervisory control and data acquisition, state estimation, on-line load flow, security assessment, economic dispatch, automatic generation control, optimal power flow, security constrained economic dispatch, multistage rescheduling and equivalents. The required text was Power Generation, Operation and Control, 2nd edition by Wood and Wollenburg. This course was not offered during the academic year 2002-2003.

ECE 476 Dynamics and Stability of Power Systems

The course includes the dynamic representation of interconnected power systems - electrical plus mechanical, linearized dynamic models of multimachine systems, methods of coherency identification, order reduction by singular perturbation, time scale decomposition and aggregation techniques, dynamic equivalents, direct methods of stability analysis and power system stabilizer design. The required text was Power Systems Dynamics and Stability by P. W. Sauer and M. A. Pai. The total enrollment for the academic year 2002-2003 was 17. This course is also available by web-based education.

ECE 488 Electricity Resource Planning

This course provides coverage of the basic techniques in electric utility resource planning including methodologies for reliability evaluation and assessment, production costing, marginal costing, supply-

side and demand-side planning and integrated resource planning. Throughout the course, probabilistic approaches are emphasized. In place of a text, notes specifically prepared by George Gross are used. The total enrollment for the academic year 2002-2003 was 11.

ECE 490I Power and Energy Systems Area Seminar

This course is a graduate seminar on advanced topics of current interest. Both faculty and students participate by presenting either current research results or topics of interest in journal publications. Guest speakers from industry and other universities are also scheduled periodically throughout the semester. The total enrollment for the academic year 2002-2003 was 54.

ECE 497PE Power Electronic Devices and Systems

This advanced course in power electronics considers the unique devices and models used for switching energy conversion systems. Emerging nonlinear approaches to operation and control are discussed. Design issues for fast dynamic converters are presented. The goal of the course is to provide students with a rich background in the broad issues of high-performance power electronics at the graduate level. Specific topics include magnetic device design, power semiconductor device models, interfaces and gate drives, small-signal and large-signal converter control models. Averaging methods are presented for power converters. Concepts and methods of geometric control are addressed. The required text is Elements of Power Electronics by P.T. Krein. This course was not offered during the academic year 2002-2003.

ECE 497PH Hybrid Systems Analysis of Power System Dynamics

The purpose of the course is to present a new approach to the analysis of large scale complex networks, such as power systems, by viewing them as interconnections of dynamic devices, discrete devices and algebraic constraints. Such hybrid systems can display very interesting forms of behavior. Trajectory sensitivity analysis used as a tool for security monitoring, stability analysis and model verification. Aspects of hybrid system control are presented. This course was not offered during the academic year 2002-2003.

ECE 497PS Power System Modeling and Analysis

This is a newly developed half-semester graduate course in the modeling of power systems in the steady state and dynamic regimes. It includes the analysis and simulation techniques for power and power electronic systems as well as computational issues in power systems and power electronics. Topics covered are: advanced power flow, sparsity techniques, power flow control, least squares and

estimation applications averaging techniques for power electronic systems, numerical integration of differential equations. The course uses the notes of George Gross in lieu of a text. This course was not offered during the academic year 2002-2003.

ECE 497TO Issues in Competitive Electricity Markets

This course provides an introduction to competitive electricity markets. The course covers topics including market structures and paradigms, transmission services, transmission congestion management, allocation of real power losses, optimal bidding strategies, and market power analysis. This course was not offered during the academic year 2002-2003.

NUMBER OF ELECTRIC POWER AND ENERGY SYSTEM AREA GRADUATES IN RECENT YEARS

1950-1970 Annual Average Power Area Graduates

B.S.E.E.	-	25
M.S.E.E.	-	3

1970-1980 Annual Average Power Area Graduates

B.S.E.E.	-	44
M.S.E.E.	-	7

1980-1990 Annual Average Power Area Graduates

B.S.E.E.	-	32
M.S.E.E.	-	5
Ph.D.	-	2

1990-1995 Annual Average Power Area Graduates

B.S.E.E.	-	40
M.S.E.E.	-	6
Ph.D.	-	2

1995-2000 Annual Average Power Area Graduates

B.S.E.E.	-	35
M.S.E.E.	-	9
Ph.D.	-	3

2000-2002 Power Area Graduates

B.S.E.E.	-	36
M.S.E.E.	-	8
Ph.D.	-	3

2002-2003 Power Area Graduates

B.S.E.E.	-	43
M.S.E.E.	-	8
Ph.D.	-	2

5. ACTIVITIES

The faculty and students in the Power and Energy Systems Area participated in a considerable number of special activities during the calendar year 2002. The major events are listed below:

- Hawaiian International Conference on System Science, Hawaii, January
  - Tom Overbye presented a paper and chaired mini-track
  - Pete Sauer chaired two sessions
- M.A. Pai visited the Indian Institute of Science in Bangalore, India, the Central Power Research Institute, IIT Madras giving seminars & collaborating with IIT Madras in IT in Ag. Extension (Jointly with Ag. Extension at UIUC), January 2002
- Philip Krein participated in the 2003 Future Energy Challenge Organizational Meeting in Pittsburgh, PA, January
- Pat Chapman attended a workshop on World Trade Center Consulting, January
- Philip Krein presented a seminar in the ECE department at Michigan State University, January
- George Gross attended a meeting of the Editorial Board of Electra, the international journal of CIGRE in Paris, France, January
- Ian Hiskens attended a workshop on teaching power electronics in Phoenix, AZ, January
- George Gross attended the Federal Reserve Bank colloquy on electricity restructuring in Chicago, IL, January
- EEE Power Engineering Society Winter meeting in New York, NY, January
  - George Gross made presentations and attended editorial board meetings and a CIGRE meeting
  - Tom Overbye attended board meetings
  - Pete Sauer chaired a panel and
  - Ian Hiskens chaired a committee meeting and paper session and made panel and paper presentations
- George Gross and Pete Sauer participated in the NSF Proposal Review Panel in Arlington, VA, February
- Tom Overbye attended a technical program committee meeting for the Power Systems Computations Conference in Zurich, Switzerland, February
- Ian Hiskens participated in technical discussions at University of Wisconsin, Madison, February
- Pete Sauer chaired the PSERC Executive Committee meeting in Santa Fe, NM, February

- George Gross met with colleagues at Purdue University to discuss the preparation of a joint proposal, February

- Tom Overbye presented a Sigma Xi lecture at University of Georgia, February

- Ian Hiskens visited Drexel University for discussions on NSF grant proposal and presented a seminar, March

- Pete Sauer and Philip Krein visited the Grainger Foundation in Chicago, IL, March

- APEC meeting in Dallas, TX, March

  - Philip Krein presented a paper and attended the IEEE Power Electronics Society Administrative Committee and other meetings
  - Pat Chapman attended
  - Graduate students Xin Geng, Zakdy Sorchini and Marco Amrhein also attended

- EEI Transmission Business School in Philadelphia, PA, March

  - George Gross directed and taught
  - Tom Overbye gave a presentation

- Pete Sauer attended EMCWA meeting and visited San Diego Gas & Electric in San Diego, CA, March

- Tom Overbye discussed power system visualization with the National Center for Atmospheric Research in Boulder, CO, March

- Pat Chapman attended a planning meeting with Energy System Analysis Consortium in West Lafayette, IN, March

- Tom Overbye presented IEEE/Sigma Xi lecture in Bloomington, IL, March

- Philip Krein presented a short course on fuel cell power conditions for the Department of Energy in Morgantown, WV, March

- Ian Hiskens visited the University of Newcastle, Melbourne, Australia, March for technical discussions and presentations

- Pat Chapman, Philip Krein, Pete Sauer and graduates students took a plant trip at Emerson Motor Corp. in St. Louis, MO, March

- Ian Hiskens participated in an NSF workshop in Mexico, April

- Tom Overbye attended the PJM annual meeting in Pittsburgh, PA, April

- Pete Sauer and six students attended the American Power Conference in Chicago, IL, April

- Philip Krein served on the NSF Site Visit Panel for the Center for Power Electronic Systems in Blacksburg, VA, April

- Tom Overbye participated in the Illinois Electric Council Annual Meeting in Springfield, IL, April

- Pete Sauer participated in the IEEE workshop on manpower in St. Louis, MO, May

- Ian Hiskens, Northwestern University and MIT, Boston, MA, May

  - Presentations
  - Technical discussions

- Philip Krein served on a review panel for the Department of Energy programs in electric machines and power electronics in Knoxville, TN, May

- Ian Hiskens attended ISCAS in Scottsdale, AZ, May

- PSERC IAB meeting in NY, May

  - Pete Sauer presided
  - Ian Hiskens and Tom Overbye attended

- George Gross and Pete Sauer participated in the CERTS Internal Program Review in Chicago, IL, June

- Pete Sauer participated on the review team for PNNL in Pasco, WA, June

- Tom Overbye presented a paper at Advanced workshop regulation and competition in South Lake Tahoe, Ca, June

- IEEE workshop on computers in power electronics in Mayaguez, Puerto Rico, June

  - Philip Krein presented a paper
  - Joe Mossoba attended and also presented a paper

- 14th Power Systems Computation and Control Conference in Seville, Spain, June 24-28,2002

  - George Gross presented two papers and chaired a session
  - Tom Overbye presented papers
  - M.A. Pai presented a paper

- IEEE Power Electronics Specialists Conference in Cairns, Australia, June

  - Philip Krein chaired a session, served as a panelist and attended committee meetings
  - Graduate students Rob Balog and Jason Wells attended

- IEEE Power Engineering Society Summer Meeting in Chicago, IL, July

  - Pete Sauer chaired sessions and presented a tutorial
  - George Gross presented two tutorials
  - Tom Overbye presented a tutorial

- M.A. Pai attended

- Tom Overbye attended the Illinois Commerce Commission Review Meeting in Springfield, IL, July

- PSERC retreat, Mount Hood, OR, August

  - Pete Sauer chaired the retreat
  - George Gross and Tom Overbye attended

- George Gross gave invited presentations at the Chilean Congress and met with policy makers and researchers to discuss electricity restructuring in Chile, August

- M.A. Pai visited the University of California at Irvine and presented a paper at the workshop on Power Electronics in Fuel Cells, August 2002

- Pete Sauer visited Wisconsin Power & Light plus Cooper Systems about PSERC in Milwaukee, WI, August

- Philip Krein discussed the Grainger Award program and research activities in Seattle, WA, August

- Tom Overbye attended Illinois Commerce Commission review meeting in Springfield, IL, September

- Pete Sauer attended the NSF workshop on Critical Infrastructure Protection in Washington, DC, September

- EEI Transmission Business School in New York, NY, September

  - George Gross directed and gave presentations
  - Tom Overbye gave a presentation

- IEEE INTELEC Conference, Montreal, Canada, September

  - Philip Krein attended IEEE Power Electronics Society Adcom Meeting participated in the IEEE INTELEC Conference
  - Rob Balog presented a paper at INTELEC Conference

- Pete Sauer attended an IEEE Committee Meeting in Newark, NJ, September

- Pat Chapman presented a paper at the IAS Conference in Pittsburgh, PA, October

- Pete Sauer presented PSERC research program to 5 companies in Atlanta, GA, October

- Tom Overbye attended the National Academy of Engineering Frontiers in Engineering Organizational meeting in Tokyo, Japan, October

- Philip Krein, Pete Sauer and Pat Chapman attended the EPNES program meeting at the National Science Foundation in Arlington, VA, October

- Pete Sauer presented the UIUC power program to MidAmerican Energy in Davenport, IA, October

- George Gross participated in a PSERC meeting to discuss comments on the FERC notice of proposed rulemaking, Chicago, IL, October

- Pete Sauer and scholarship students attended the EMCWA Expo in Cincinnati, OH, October

- Tom Overbye and Pete Sauer attended the North American Power Symposium in Phoenix, AZ, October

- Philip Krein gave an invited talk at ETTC committee meeting in Rosemont, IL, October

- Pete Sauer visited IREQ to discuss PSERC research activities in Montreal, Canada, October

- George Gross directed and presented the Basic Power short course at the American Transmission Company in Waukesha, WI, November; Pete Sauer and Tom Overbye also presented

- Philip Krein participated in discussions of motor testing and the Future Energy Challenge at Advanced Energy in Raleigh, NC, November

- Pat Chapman visited the Otis Electric Research Facility in Farmington, CT, November

- Philip Krein attended IEEE Board Meeting series in Itasca, IL and presented an invited talk at IEEE meetings at Northern Illinois University, November

- National Energy Supergrid workshop in Palo Alto, CA, November

  - Tom Overbye organized and attended
  - George Gross also attended and met with colleagues working on electricity problems in San Francisco, CA

- George Gross participated in the NSF workshop in New Orleans, LA, November

- Philip Krein made presentations at the joint US/Jordan NSF workshop on Modern Power Electronics Research and Education, Amman, Jordan, December

- George Gross participated in a CERTS meeting to discuss follow-on work on the National Transmission Grid Study in Washington, DC, December

- Tom Overbye met with the Illinois Commerce Commission in Springfield, IL, December

- George Gross and Pete Sauer made a presentations at the PSERC Industrial Advisory Board meeting in Atlanta, GA, December

- Tom Overbye discussed electric industry restructuring with the Tennessee Valley Authority in Chattanooga, TN, December

- Hosted the following guest speakers:

- Steven Pekarek, University of Missouri – Rolla, "On the Use of Singular Perturbations to Neglect the Dynamic Saliency of Synchronous Machines," March
- S.D. Sudhoff, Purdue University, "Next Generation Shipboard Power and Propulsion Systems," April
- Keith Corzine, University of Wisconsin – Milwaukee, "Multi-Level Power Conversion," June
- S.A. Soman, I.I.T., Bombay, "A Three Tier Object Oriented Architecture for Power System Computations," June
- Soumitro Banerjee, I.I.T., Kharagpur, "The Theory of Bifurcations in Hybrid Systems," June
- Costas D. Vournas, NTV Athens, Greece, "Investigation of Nonsmooth Points of Power System Loadability Surface," July
- Russell MacAdam, Lutron Electronics Co., Inc., "Dimming of Fluorescent Lamps," September
- Jennifer Sterling, ComEd, "The Standard Market Design Initiative," November

- Presented the following seminars by UIUC faculty and students:

  - Joseph Mossoba, "Unit-Delay Deadbeat Control of a High Bandwidth Active Power Filter," January
  - Patrick Chapman, "Fundamental Questions About Torque and Force in Electric Machinery," February
  - Zakdy Sorchini, "Power Line Proximity Estimation," February
  - Ian Hiskens, "Inverse Problems in Power Systems," February
  - Worapot Tangmunarunkit, "Optimization of Load Shedding Against Voltage Instability," March
  - Vaibhav Donde, "Analysis of Hybrid Limit Cycle Stability in a System Including Tap-Changing Transformer," March
  - Scott Dahman, "Demand-Side Risk Management in Electricity Markets," March
  - James Owens, "Proposed Finite Element State-Space Representation for Linear Magnetic Devices," April
  - Minghai Liu, "Effectiveness of the Distribution Factor Approximations Used in Congestion Modeling," April
  - Philip Chorazy, "Visualization Techniques for Power System Analysis Software," April
  - Joseph Mossoba, "Small Signal Modeling of Sensorless Current Mode Controlled dc-dc Converters," September
  - Tony B. Nguyen, "Dynamic Security-Constrained Rescheduling of Power Systems Using Trajectory Sensitivities," September
  - Surya Musunuri, "Fully-Integrated CMOS DC-DC Converters," September
  - Patrick Chapman, "Induction Machine Drive Model for Analyzing Switch-Frequency Torque and Current," October

- Minghai Liu, "Congestion in Power System Operations," October
- Jason Wells, "Ripple Correlation Control of Electric Machinery," October
- Jean-Baptiste Heyberger, "Transmission Line Modeling in Transient Analysis," October
- Philip Krein, "Fuel Cells: Electrical Energy Conversion Issues," November
- Marco Amrhein, "Rotor Designs for Small Inverter-Dedicated Induction Machines," November
- Philip Krein, "The Nature and Promise of a 42 V Automotive Power: An Update," December
- Paola Caro-Ochoa, "Evaluation of the Market Efficiency Impacts of Congestion," December

6. RESEARCH FUNDED BY OTHER SOURCES

The Power Affiliates Program is a source of seed money, which enables the faculty to obtain support from major funding agencies. The following pages summarize the projects, which have been made possible through this growth.

A Hybrid Approach to Transport Industry Modeling – A Power System Viewpoint

M.A. Pai, I.A. Hiskens, V. Donde, W. Tangmunarunkit

National Science Foundation, ECS 0085755

Transport systems have much in common with power systems. This project is addressing basic issues that provide a common framework in terms of analysis, synthesis and optimization. Transport systems typically involve distributed agents that are forced to share some common resources. The agents associated with many transport industries exhibit continuous dynamics. However the scheduling of the agents involves discrete events. This project focuses on the modeling and analysis of such hybrid systems that typify transport industries. Current tools for analyzing hybrid systems are inadequate. The project is developing algorithms that address inverse problems (typically design issues) in transport systems.

Alternative Business Models for Transmission Investment and Operation

Shmuel Oren, UC Berkeley, George gross and Fernando Alvarado, University of Wisconsin

CERTS for the Department of Energy

As part of the National Transmission Grid Study, we undertook the assessment of various models for investment in and operation of transmission. The central question that our study addresses is what transmission system governance structure and business model can most effectively support the objective of promoting competition through nondiscriminatory access to the grid. Transmission system business models define the relationship among the three basic business functions associated with the provision of transmission service: system operation, market design and operation, and grid ownership. The study addresses the salient requirements of a well functioning transmission system. The range of options is reviewed and recommendations for the structures in the transmission restructuring debates are presented.

Analysis of Load Frequency Control Performance Assessment Criteria

George Gross and J. W. Lee

PSERC

This research addresses the development and application of an analytic framework for the formulation and evaluation of control performance criteria in load frequency control (LFC). The framework is constructed so as to explicitly represent the uncertainty in the measured variables in LFC and to use metrics that are meaningful for the structure of the problem. The framework makes effective use of probability and random processes concepts to develop rather general criteria for LFC performance assessment. In fact, the NERC criteria ***CPS1*** and ***CPS2*** are special cases of the criteria of the framework. The paper thus provides an analytic rationale for the NERC control performance criteria. Analysis of the ***CPS1*** and ***CPS2*** criteria shows that, under conditions that are typically in effect in North American interconnections, the two criteria are redundant. Consequently, there is good

analytical basis for not requiring the application of ***CPS2*** once ***CPS1*** is satisfied. Numerical results with various interconnections are performed to illustrate the analytic results. The framework is a powerful construct that may be used to construct new criteria for LFC performance assessment.

Applications of GaN Technology to Power Electronics

P.L. Chapman, K. Kim, P. Krein

Grainger Center for Electric Machines and Electromechanics

Recent advances in GaN semiconductor devices will enable new developments in the power electronics area. GaN diodes and transistors can operate at higher temperature, speed, and voltage than the Si counterparts. Some recent publications state that GaN, as opposed to SiC, is the material of the future for power. This project will investigate the use of these devices in several typical power electronics applications, as well as at least one application not previously possible with Si technology. GaN based JFET's and HEMT's have been developed and will be tested soon in a power converter application.

Autonomous Optimal Control of Induction Machine Drives

P.L. Chapman*, P.T. Krein*, J.R. Wells

Grainger Center for Electric Machinery and Electromechanics

Direct Torque Control (DTC) of induction machine drives is a straightforward method of decoupling torque and flux that in itself provides for fast response and minimal parameter sensitivity. However, setting the flux command in DTC for optimal efficiency, like most other methods of optimal control of induction machine drives, relies heavily on parameterization or involves sacrificing response time. A parameter insensitive optimization routine, known as ripple correlation control that interferes minimally with the dynamic response of the system has been developed. The control utilizes the perturbations inherent in power electronics driven motor drives to test for optimality of the operating point. Since the perturbations are at high frequency, the optimization has high bandwidth. The machine parameters are not critical in this robust control.

Available Transfer Capability of Power Systems

P. W. Sauer,* S. Grijalva

National Science Foundation, EEC 0120153

This project examines new approaches to the rapid computation of available transfer capability in electric power systems. It focuses on efficient techniques to simultaneously include thermal, voltage, voltage collapse, and transient stability margin constraints. New approaches to quantify the transmission reliability margin and capacity benefit margin are investigated.

Battery Equalization in Series Strings

P. T. Krein,* R. Balog

Grainger Endowment

Batteries are usually used in series strings. When a string is charged, the individual cells can become mismatched. Over time, this mismatch can grow, particularly if extreme temperature conditions

occur. Mismatch is corrected by equalization, in which the battery voltages are forced to match. This is usually accomplished with elevated voltage applied after the end of a charge cycle. This project studies an elegant equalization method invented at the U of I. A capacitor string is switched between adjacent batteries, forcing them to reach a matching condition whether or not they are charging. Life tests are being carried out to confirm matching requirements and performance.

Congestion Management Allocation Mechanism for MultipleTransaction Systems

G. Gross,* S. Tao

EPRI/DoD and CERTS

We investigate the allocation of charges for congestion management (CM) in multiple transaction networks. We develop a physical-flow-based congestion management allocation mechanism by applying the multiple transaction network framework constructed for the loss allocation problem. We determine the contribution to congestion attributable to each transaction on a physical-flow basis. This allocation scheme explicitly addresses the issue of counter flows. The allocation results are used in the Independent Grid Operator (IGO)'s congestion relief so as to allow it to acquire relief services to remove the overload congestion attributed to each transaction from the network in the most economic manner. The congestion charges attributable to each transaction for its usage of the network are also determined. We tested the proposed scheme on several systems and we illustrate its capabilities on a network based on the IEEE 57-bus system. We discuss the policy implications of the congestion relief allocation solution. The proposed scheme provides physically reasonable results and is applicable to large-scale networks.

Coupled Filter Applications to DC Power Converters

P. T. Krein,* D. C. Hamill (Surrey), R. Balog

Grainger Endowment in collaboration with the University of Surrey, England; INTELEC Fellowship

Coupled magnetic filters offer performance improvements in dc switching power circuits, but are not well understood in the field. In fact, one key coupled filter building block has been reinvented several times over an interval of 60 years or more. This work seeks a fundamental understanding of coupled filter design, performance, and applications. Coupled filters are compared with more conventional approaches for design sensitivity and utility. Automatic tuning strategies are being explored for coupled filter applications.

Development of an Analytical Framework for Strategic Bidding in Competitive Electricity Markets: Modeling and Policy Analysis

George Gross, George Deltas UIUC Department of Economics

National Science Foundation, ECS-0000577

The work is on the design, functioning and performance of competitive mechanisms in wholesale electricity markets taking explicit account of the specific characteristics and constraints of electrical generation and consumption. The objective is to develop a very general and comprehensive analytic framework that integrates the game theoretic aspects of electricity exchanges with the unique constraints under which electric power systems operate. This framework will lay the foundation for the evaluation of various designs for electricity market structures and 'rules of the road' of auction mechanisms that incorporate the constraints imposed by the physical/engineering/operational constraints inherent in electricity systems, so as to maximize economic efficiency. The in-depth

analysis of the structural characteristics of electricity markets will provide a basis for the formulation of optimal bidding/offering strategies with both supply- and demand-side bidders. We aim to use the framework to address the various aspects of the implementation and performance of auctions for electricity; the explicit incorporation of uncertainty; the interrelationships between the MWh commodity markets and specific markets in ancillary services; and, the impacts of longer term forward and future markets. These issues will be investigated together with topics related to the opportunities for gaming, the existence and exercise of market power and the impacts on electricity prices. In addition, the framework will serve as an effective test bed for a wide range of policy experiments including those focused on the nature and scope of regulation in the restructured industry. Throughout the proposed work we will implement simulation tools to illustrate the performance of various market designs, rule specifications, regulatory policies, and strategic behavior of various players.

Direct Digital Class-D Audio Amplifier

P. T. Krein,* D. Sarwate,* Z. Song, X. Geng

Motorola, Inc.; University of Illinois

Conventional "linear" audio amplifiers have low power efficiency. In modern digital audio systems, amplifiers require digital-to-analog conversion, with the associated noise sensitivities and signal problems. Class-D amplifiers operate by direct pulse-width modulated (PWM) switching, and in principle can be free of power loss. Because class-D circuits operate by switching, it is feasible to maintain the audio information in digital form right through to the amplifier output. We explore audio processing to convert from conventional digital formats to PWM. Class-D circuit design methods are being developed to support audiophile performance with very low power loss.

Effectiveness of the Distribution Factor Approximations Used in Congestion Modeling

Minghai Liu and George Gross

CERTS

Congestion has widespread impacts on the availability and utilization of the existing transmission systems and consequently on the operation of competitive markets in electricity. The distribution factors play a key role in the modeling of congestion in various market applications. These factors are linear approximations of sensitivities of variables with respect to various inputs and are computed for a specified network topology and parameter values. In practice, the factors are used over a wide range of system conditions. This research investigates the analytical characteristics, the robustness and the quality of the approximations provided by key distribution factors such as injection shift factors (*ISF*s) and power transfer distribution factors (*PTDF*s). We examine the range of conditions over which these factors can provide a reliable approximation for large power system networks. The numerical simulation results indicate that the errors of the approximations stay in an acceptable range under a broad spectrum of conditions including contingencies used to establish *n-1 security*. Application to fixed transmission rights is under investigation.

Evaluating the Potential for Transmission Constraints on the Operation of a Competitve Electricity Market in Illinois

Tom Overbye,* Oscar Munoz, Xu Cheng,

Illinois Commerce Commission

The goal of this project is to determine if the transmission system in Illinois and the surrounding region is able to support a competitive electricity market. That is, one which would allow for effective competition to keep prices in check, and allow for new market participants to effectively compete for market share. The project will seek to determine if there are conditions that could reasonably be expected to occur that would enable a company to exercise market power in one or more portions of the State and thereby create undue pressure on the prices charged to customers and/or inhibit new market participants from entering the market. It should be noted that the intent of this project is not to predict whether or not any company would actually exercise such market power. Rather, it is designed to determine if a set of reasonably expected conditions could allow any company to do so.

Extended Factors for Linear Contingency Analysis

P. W. Sauer,* K. Reinhard

Grainger Foundation

This project is formulating new computational factors to extend linear contingency analysis to include phenomena such as angle shifts and generator torque changes in response to line outages or closings. The factors build on well-known power transfer distribution factors and line-outage–distribution factors.

Extraction of Low-Order Models from Finite Element Representations of Electromechanical Devices

P.L. Chapman, James Owens

Grainger Center for Electric Machines and Electromechanics

In designing complicated electromechanical systems it is imperative to have accurate, rapidly executing dynamic models. Traditional lumped-parameter models are not usually as accurate as desired, since they rely on many assumptions in development and parameter extraction. In many respects, the finite element method is a convenient means for eliminating some discrepancies, but the method is very computationally intensive. This project seeks to develop a methodology to extract a computationally non-intensive model from an ordinary finite element representation. The resulting model will retain the salient features of the finite element model, but execute rapidly enough to enable designers to consider many designs and simulate large systems with many devices.

Fully Integrated Switch-Mode Power Supplies

P.L. Chapman, C. Liu, Surya Musunuri, Jun Zou

Grainger Center for Electric Machines and Electromechanics

Miniaturization is of supreme interest in all facets of electronics design. Power management is no exception. While power supply components have shrunk considerably in the last decades, the size decrease is limited by the large passive components. Recent developments in MEMS technology have enabled fabrication of microscale inductors and capacitors in three dimensions. Coupled with the integrated switching devices, an entire power converter can be built on a single chip. The integration, which in itself results in a small package, eliminates many of the parasitic effects, and enables one to use higher switching frequency, thereby reducing the size of passive components needed.

Integrated Security Analysis

P. W. Sauer,*

Power Systems Engineering Research Center (PSERC)

This project is formulating new security analysis tools for operators using existing computational software code with on-line data. Traditional security application programs are used to create historical security results, which will be used to develop learning algorithms that will use both new computational results and historical results. This work is being jointly done with Washington State University.

Interactive Visualization of Electrical Power System Transmission System Capacity

Tom Overbye,* Doug Wiegmann, Yan Sun

Power Systems Engineering Research Center (PSERC)

One of the major goals associated with restructuring in the electrical power industry is to allow nondiscriminatory access to the high voltage transmission grid. However a key difficulty in achieving this goal has been the fact that the capacity of the transmission grid has a finite but not easily determined value. That is to say, the ability of the transmission system to support additional power transactions is limited by the need to maintain system security. The goal of this project is to develop and apply innovative visualization methods to aid market participants in determining this availability.

Inverse Problems in Power System Dynamics

I.A. Hiskens, D. Liberzon, M.A. Pai

National Science Foundation, ECS 0114725

Analysis of power system dynamic behavior frequently takes the form of *inverse problems,* where the aim is to find parameter values that achieve (as closely as possible) a desired response. Examples include parameter estimation, quantifying parameter uncertainty, boundary value problems, and optimal control. The project is developing algorithms for solving such inverse problems. Power system behavior inherently involves interactions between continuous dynamics and discrete events. A systematic *hybrid systems* framework for modeling, analysis and algorithms is being pursued.

Inverter-Dedicated Induction Motor Design

P. T. Krein*, M. Amrhein

Grainger Center for Electric Machinery and Electromechanics

Most ac motors today are designed to start and operate directly from the utility line. Design choices must be made to manage starting current and torque. The fraction of motors that is powered from an electronic inverter is increasing rapidly. In these motors, control can be used to avoid the challenges of direct line connection. A motor designed from the beginning for inverter input has the potential for better efficiency and higher maximum torque compared to conventional designs.

Limit Cycles in Hybrid Systems

I.A. Hiskens, M. Spong

National Science Foundation, ECS 0114725

Limit cycles are common in hybrid systems. However the non-smooth dynamics of such systems makes stability analysis difficult. We have been using recent extensions of trajectory sensitivity analysis to obtain the characteristic multipliers (eigenvalues) of non-smooth limit cycles. These eigenvalues determine the stability of a limit cycle. Numerous applications have been explored, from power electronic circuits through to the walking motion of a biped robot. Period-doubling bifurcations have been explored. Shooting methods for locating non-smooth limit cycles (both stable and unstable) have been developed.

Minimizing Failures While Maintaining Efficiency of Complex Interactive Networked Systems

P. W. Sauer,* M. A. Pai, I. Hiskens

EPRI/DoD

This project is task 2 of the overall EPRI/DoD project with this title. This task will formulate the overall design of a link-based mathematical model that can accommodate key functional and structural attributes necessary to analyze the interaction between layered systems. It will use the four-layer power system as the testing ground for applications.

Multi-layer Systems

I. A. Hiskens, P. W. Sauer, M. A. Pai

EPRI/DoD

Communications networks play a significant role in the multi-layer representation of power systems. The communications network model being proposed is based on a conceptual abstraction involving finite channel and node capacities that trigger changes in message transmission delays. Numerical integration of systems that incorporate such variable time delay models is not straightforward. This is especially so when considering the switched (hybrid) nature of system behavior. The project is investigating various techniques to handle variable time delays within numerical integration techniques. An important criterion is that algorithms must be capable of efficiently computing trajectory sensitivities.

Multiple Carrier, Multiple Signal Methods for Pulse Width Modulation

P. T. Krein*, X. Geng

Grainger Center for Electric Machinery and Electromechanics; Motorola, Inc.

Power converters and switching amplifiers use pulse width modulation (PWM) to process energy. This is required to deliver a high-quality waveform from discrete energy sources. A multi-signal multi-carrier PWM approach is being developed that enhances the flexibility of PWM. For example, the new approach supports high-frequency isolation. It can deliver several signals, such as the three phases of a motor drive, with a single PWM data stream. The approach has application in low-cost inverters and multi-channel switching amplifiers.

New System Control Methodologies

M.A. Pai, I.A. Hiskens, A. Nayak, C.L. DeMarco (Univ. of Wisconsin)

Power Systems Engineering Research Center (PSERC)

In this research, we are looking at the effect of dynamic control in the new deregulated environment. In previous research we looked at AGC in the new restructured environment. The two area AGC block diagram was modified to take into account the bilateral contracts. We have investigated congestion related problems and their alleviation using a OPF frame work. Bilateral contracts are considered in the formulation. Developments in the optimal control of hybrid systems are being explored for tuning non-smooth elements of power systems.

Optimal Bidding Strategies in Transmission Limited Electric Power Markets

Tom Overbye,* Ian Hiskens, Pedro Correia

National Science Foundation, ECS 00-80279

The electricity industry in the United States and throughout the world is undergoing radical restructuring, with many markets moving from a cost-based paradigm for generation dispatch to a price-based paradigm. These changes require new analysis techniques, both for market participants and for regulators. The goal of this project is the development of a market solution algorithm that allows market participants to determine optimal generation bidding strategies taking into account the constraints imposed by the electric power transmission grid.

Optimal Diversification of Multiple Energy Sources

P.L. Chapman

National Science Foundation

This is an integrated research and education project aimed at improving the use of energy in terms of efficiency and the environment. Power converters that draw energy from multiple sources in an optimal, diversified way will potentially provide the user with a very robust and 'green' energy source. The research is supported by new coursework in energy related topics.

Optimal Load Shedding to Alleviate Voltage Instability

I.A. Hiskens, W. Tangmunarunkit

National Science Foundation, ECS 0114725

Load shedding provides an effective (though drastic) control strategy for alleviating voltage instability. However the disruption to consumers caused by load shedding should be minimized. This project is developing optimal control techniques that are applicable in this hybrid system setting. The aim is to determine locations and shedding times that minimize the total shed load.

Optimal Power Flow Application Issues in the Pool Paradigm

The Italian Fulbright Commission and the U.S. State Department and PSERC

Ettore Bompard, Politecnico of Torino, and George Gross

The research focuses on the application of the Optimal Power Flow (OPF) to competitive markets. Since the OPF is a central decision-making tool its application to the more decentralized decision-making in the competitive electricity markets requires considerable care. There are some intrinsic challenges associated with the effective OPF application in the competitive environment due to the inherent characteristics of the OPF formulation. Two such characteristics are the flatness of the

optimum surface and the consequent continuum associated with the optimum. In addition to these OPF structural characteristics, the level of authority vested in the central decision-making entity has major ramifications. These factors have wide ranging economic impacts, whose implications are very pronounced due to the fact that, unlike in the old vertically integrated utility environment, various market players are affected differently. The effects include price volatility, financial health of various players and the integrity of the market itself. We apply appropriate metrics to evaluate market efficiency and how the various players fare. We study the impacts of OPF applications in the Pool paradigm, with both supply and demand side explicitly modeled, also through extensive numerical simulations. The numerical results show the variability of nodal prices and the skew possible in different "optimal" allocations among competing suppliers. Such variability in the results may lead to serious disputes among the players and the central decision-making authority.

Optimized Waveshaping for PM Motor Drives with Unbalanced, Arbitrary, and Asymmetrical Back EMF

P.L. Chapman, Alan Wu

Grainger Center for Electric Machines and Electromechanics

By precisely shaping the current in permanent magnet motor drives, considerable improvement in performance can result in terms of efficiency and vibration. Previous work in this area has limitations in that it requires the motor emf to be balanced, symmetrical, and to otherwise be restricted in shape. By eliminating these restrictions, a more flexible control has been developed. An important consequence is that with this control, the motor can be operated with one or more phases absent with only some degradation in power output.

Parameter Values that Induce Marginal Stability

I.A. Hiskens, I. Dobson (Univ. of Wisconsin, Madison)

Power Systems Engineering Research Center (PSERC) and Grainger Foundation

Stability limits place restrictions on power system operations. Calculation of these limits is therefore very important, but is also quite difficult. This project is exploring algorithms for determining parameter values that result in marginal stability of a system. (A system is marginally stable for a particular disturbance if the post-disturbance trajectory lies on the stability boundary.) A nonlinear least-squares formulation has been developed to determine a *critical* set of parameter values. Other approaches that are based on boundary-value problems are being explored. In order to maintain marginal stability, perturbations in some parameters must be matched by compensating changes in other parameters. The project is developing sensitivity relationships between the two groups of parameters. These sensitivities form the predictor in a predictor-corrector continuation method for tracing the parameter space view of the stability boundary.

Power Flow Solution Space

I.A. Hiskens

Grainger Foundation

Knowledge of the structure of the power flow solution space is important when analyzing the robustness of operating points. Unfortunately, that structure has not been clearly established. As part of this project, a predictor-corrector technique has been developed to assist in exploring the solution space boundary. Using that technique, it has been found that the solution space may contain holes, even for very simple systems. This project is characterizing the solution space structure for various

sub-classes of systems. The ultimate aim is to see how far those results can be extended for general systems.

Power Industry Restructuring And Pricing in Siberia

Sergei Palamarchuk and George Gross

Bureau of Educational and Cultural Affairs, US Department of State

The restructuring of the power industry in Russia is underway. The existing nation-wide market is planned to be divided into three regional sectors, one of which will be set up in the Siberian region of the country. The restructuring will allow the market arrangements to take into account the regional characteristics of electricity generation, transmission and consumption.
The project aims to develop the auction mechanism for the wholesale electricity trade in Siberia. Key aspects include the review of the market structures currently in operation, the design of the market forward trade and the associated pricing issues, the procedures for the evaluation of rational bidding strategies for market players and the training of the players in the new environment.

Power Line Proximity Sensor for Construction Applications

P. T. Krein*, S. Franke*, Z. Sorchini

Grainger Center for Electric Machinery and Electromechanics

Contact with both overhead and underground electric utility lines is a major problem in the construction industry. Safety hazards, loss of service, and repair fees take a high human and economic toll. Development of convenient low-cost sensors that can provide a real-time warning of power line proximity is the objective. In many environments, the strong electric fields around power lines offer a way to sense them. When equipment comes too close, safety interlocks can warn the operator or force a shut down.

Procedure For The Acquisition Of Capacity-Based Ancillary Services

Gianfranco Chicco, Politecnico of Torino, and George Gross

National Science Foundation, ECS-0000577 and PSERC

We studied the competitive procurement of capacity-based ancillary services (AS) in unbundled markets by the Independent Grid Operator (IGO). These AS include upward frequency control, load following and the range of reserve services, which may be procured from unloaded capacity offered by both on-line and off-line sources. The capacity-based AS are prioritized in order of ascending response times. Prioritization allows substitutability of the AS by automatically making the unused capacity of a higher priority AS usable for any lower priority AS without the need of submitting additional offers. We formulated the auction structures for the acquisition of the prioritizable capacity-based AS and developed an efficient scheme for minimizing the costs incurred by the IGO by using the *rational buyer* procedure. The proposed scheme adopts effective discrete programming techniques that exploit the structural characteristics of the problem for handling the multi-auction formulation. The proposed bounding scheme takes fully advantage of critical physical constraints such as ramp rate, capacity limits, and inter-zonal constraints. We illustrated the effectiveness and computational efficiency of the proposed scheme with extensive numerical examples.

Reactive Load Modeling Impacts on Nodal Prices in Pool Model Electricity Markets

Ettore Bompard, Politecnico of Torino, and George Gross

The Italian Fulbright Commission and the U.S. State Department and PSERC

The project is concerned with the interpretation of the nodal prices in competitive electricity markets based on the Pool paradigm. Such prices are the byproducts of the optimization performed by the independent grid operator (IGO) to determine the centralized economic dispatch taking into account all the transmission network and the physical/operational constraints. The IGO implicitly takes into account congestion considerations in determining the centralized economic dispatch. Under the Pool paradigm, a system marginal price no longer exists and each bus may have a different real and reactive power nodal price due to line losses and congestion avoidance considerations that can arise when the limit of one or more constraints is reached. The objective is to explore the economic signals provided by these prices and effectively apply them in the design of markets and the *rules of the road* for these markets. The main focus of the research is on the explicit evaluation of the impacts of the reactive load on the nodal real and reactive prices. We adopt a rather general model for the representation of the reactive load: the reactive load at each node is represented as an affine function of the real power load at that node, i.e., the reactive load is the sum of a constant and a constant power factor component. This model includes as special cases the constant reactive load and the constant power factor load including the case of purely real load corresponding to unity power factor. We investigate the relationship between the real and reactive nodal prices and evaluate the impacts on them of the dual variables due to the various other physical/operational constraints in the system. We study the significance of the nodal price observations and the effective utilization in developing appropriate price signals in the Pool paradigm.

Reliability Tools for Power System Operators

P. W. Sauer,* Tom Overbye

Department of Energy/CERTS

This project is investigating advanced security analysis visualization concepts to enhance the reliability of the interconnected grid. Results from on-line security analysis will be presented and displayed to operators in a format suitable for rapid decision-making and for assessing the acceptability of the system state.

Ripple Correlation Control for Power Converters and Motor Drives

P. T. Krein,* P. Chapman,* D. Logue, R. Balog, J. Wells

Grainger Center for Electric Machinery and Electromechanics

Ripple correlation control is a new technique that might be unique to power electronic systems. According to this control approach, internal ripple signals in a power converter are correlated with gate drive signals or other internal converter signals. The results provide information about state variables and converter operating points. It is known, for example, that certain correlations can be used to drive a solar power-processing converter to its maximum power point. A wide range of applications and related techniques is being explored.

The Role of Load Demand in Elasticity in Congestion Management and Pricing

Ettore Bompard, Politecnico of Torino, and George Gross

The Italian Fulbright Commission and the U.S. State Department and PSERC

In the open access transmission regime, the *common carrier* nature of the transmission system may give rise to frequent conditions of congestion. Under such conditions, a violation of one or more

physical or operational constraints in the base case or one of the contingency cases is encountered. Congestion may result in certain cases in marked price volatility and leads to price spikes. This is particularly true in competitive electricity markets that lack demand response. In this research, we examine the role that demand responsiveness can play in competitive electricity markets.
Typically, the task of congestion management and pricing is vested in the hands of an independent grid operator (IGO). The IGO uses an optimal power flow (OPF) based tool to determine the necessary actions to relieve the system of the congestion and to determine transmission system usage charges. The actions of price responsive loads may be represented in terms of the customers' willingness to pay. From each customer's demand curve, the elasticity of the load at different prices is known and the benefit function is derived. The load at each bus ceases to be a fixed quantity and becomes a decision variable for the optimization problem of the IGO. In this way, the IGO has additional degrees of freedom in determining the necessary actions to determine congestion relief. The project investigates the impacts of load elasticity in congestion management and pricing. We analyze the salient characteristics of the optimum determined by the IGO with elastic load demand explicitly represented. We evaluate elasticity effects on consumer, producer, merchandising and social surplus. In addition, the demand responsiveness impacts on price volatility in terms of average price and standard deviation are determined and compared to the case without load responsiveness. The increase in market efficiency attainable in the presence of load responsiveness is assessed.

Security Enhancement through Direct Non-Disruptive Load Control

I.A. Hiskens, V. Vittal (Iowa State Univ.)

Power Systems Engineering Research Center (PSERC)

This project is examining novel approaches to enhancing power system reliability using direct load control. Loads that have special characteristics can be effectively controlled with minimum disruption to the customer. The analysis in this project is investigating the benefits of load control on system reliability and examining different control schemes. Due to the time-varying nature of loads, the actual amount of load available for control at any time can never be known exactly. The project is investigating ways of ensuring robustness in the presence of such uncertainty.

Stability and Optimization of Transformer Tapping

I.A. Hiskens, V. Donde, D. Liberzon

National Science Foundation, ECS 0114725

Discrete events introduced by on-load tapping of transformers can have a significant affect on the load-end dynamic behavior of power systems. This project is taking a hybrid systems approach to quantifying that behavior. Of particular interest is the stability of systems that involve cascaded tapping transformers. Limit cycles have been observed in such systems. Stability theory for switched ODE systems is being adapted to switched DAE systems, which are more common in power system applications. The project aims to devise optimal switching control strategies for minimizing tap-changer hunting.

Transmission Congestion Management Schemes: A Comparative Analysis Under a Unified Framework

Ettore Bompard, Politecnico of Torino, and George Gross

The Italian Fulbright Commission and the U.S. State Department and PSERC

The restructuring of the electricity industry has spawned the introduction of new independent grid

operators or IGOs, typically called transmission system operators (TSOs), independent system operator (ISOs) or regional transmission organizations (RTOs), in various parts of the world. An important task of an IGO is congestion management (CM) and pricing. This activity has significant economic implications on every market participant in the IGO's region. The research considers the congestion management schemes and the associated pricing mechanism used by the IGO's in five representative systems. These were selected to assess the various CM schemes in use: England and Wales, Norway, Sweden, PJM and California. We developed a unified framework for the mathematical representation of the market dispatch and redispatch problems that the IGO must solve in CM in these various jurisdictions. We use this unified framework to develop meaningful metrics to compare the various CM approaches so as to assess their efficiency and the effectiveness of the market signals provided to the market participants.

Workshop to Consider the Practicality of a Continental Energy SuperGrid

Tom Overbye*

Richard Lounsbery Foundation

The purpose of this project is to convene a workshop to investigate the technical and societal viability of a proposal for the creation of a "Continental SuperGrid" to meet our country's energy needs in the mid to later half of the 21st Century. The proposal calls for the creation of a continental grid, delivering both electricity and fuel. The electric portion of the grid would be superconducting, high voltage dc, with liquid hydrogen used as the core coolant. The electric power and hydrogen would be supplied from nuclear and other source power plants spaced along the grid. Electricity would exit the system at various dc-ac taps, connecting into the existing ac power grid. The hydrogen would also exit the grid, providing a readily available, alternative fuel, for perhaps fuel-cell based automobiles. While the scope of this proposal is certainly ambitious, given its potential for significant society-wide benefits, it is also one that deserves serious consideration and debate.

7. STUDENT PROJECTS

This section of the report contains information on the graduate students whose major research efforts were supervised by faculty in the Power and Energy Systems Area. While not all of these students received financial aid from the Power Affiliates Program in terms of Research Assistantships, they were all associated with the program through the active involvement of their respective advisors. Those students supported by the Power Affiliates Program received maximum one-half time Research Assistantships for 11 months. The results of each student's work will be made available to all affiliate companies in the form of technical reports. The following students were associated with the Power and Energy Systems Area and their work is described in the following pages:

Amrhein, Marco (M.S.)
Anders, Shaun (M.S.)
Balog, Rob (Ph.D.)
Byoun, Jaesoo (Ph.D.)
Caro-Ochoa , Paola (M.S.)
Cheng, Xu (Ph.D.)
Chorazy, Philip (M.S.)
Correia, Pedro (Ph.D.)
Dahman, Scott (M.S)
Dobbs, Bryan (M.S.)
Donde, Vaibhav (Ph.D.)
Flowers, Michael (M.S.)
Flowers, Theresa (M.S.)
Geng, Xin (Ph.D.)
Grijalva, Santiago (Ph.D.)
Güler, Teoman (Ph.D.)
Hakes, Nathaniel (M.S.)
Heyberger, Jean Baptiste (M.S.)
Ihrig, Barbara
Kwasinski, Alexis (M.S.)
Liu, Minghai (Ph.D.)
Liu, Shanshan (Ph.D.)
Louie, Henry (M.S.)
Mossoba, Joseph (Ph.D.)
Muñoz, Oscar (M.S.)
Musunuri, Surya (M.S.)
Nguyen, Tony (Ph.D.)
Niu, Penglin (M.S.)
Owens, James (M.S.)
Ray, Sheila (M.S.)
Ruiz, Pablo (M.S.)
Sierra, Vilma (M.S.)
Sorchini, Zakdy (M.S)
Sun, Yan (Ph.D.)
Tangmunarunkit, Worapot (M.S.)
Weaver, Wayne (M.S)
Wells, Jason (Ph.D.)
Wu, Alan (M.S.)
Yeu, Rodney (M.S.)
Zhang, Guoliang (Ph.D.)
Zook, Adam (M.S)

Marco Amrhein

Date of Birth:	October 13, 1977
Place of Birth:	Uzwil, Switzerland
B.S.:	December 2000, Zurich University of Applied Sciences, Winterthur, Switzerland
M.S.:	In progress

Design of Small Inverter-Fed Induction Motors

Marco Amrhein with advisor Philip T. Krein

Supported by the Power Affiliates Program

ABSTRACT

This project deals with designing a new class of small inductions motors, which should be optimized for operating exclusively in the small slip range. The design is concentrated foremost on the rotor. Goals include building and testing several motors, and compare their performance to existing induction motors. The current work includes FEM-analysis and simulations of different rotor designs, which should give enough information to find an optimal design.

Shaun Anders

Date of Birth:	February 4, 1980
Place of Birth:	Morgan Co., Illinois
B.S.:	May 2002, University of Illinois at Urbana-Champaign
M.S.:	December 2003 (expected), University of Illinois
Professional Interests:	Power quality, power system design and maintenance

Optimal Power Factor and Power Factor Correction for Utility Systems

Shaun Anders with advisor Peter Sauer

Supported by the Grainger Foundation

ABSTRACT

Power quality is increasingly more important for utilities. Specifically, low voltage issues are not only a source of system losses, but are detrimental to the performance of modern electronics and induction machines. Great potential exists to substantially alleviate these problems by applying power factor correction to distribution systems in an efficient manner. Determination of the optimal level of correction is just as critical as finding the best method to provide correction. Therefore, research shall focus on developing algorithms and heuristics to determine the optimal level of power factor correction. With these results, the most efficient and economic manner in which to implement the correction will be determined.

Rob Balog

Date of Birth:	September 18, 1974
Place of Birth:	Edison, New Jersey
B.S.:	1996, Rutgers University
M.S.:	May 2002, University of Illinois
Ph.D.:	In progress
Professional Interests:	Power electronics, analog circuits, visual environment controls, building/home automation.

Rob Balog with advisor P. T. Krein

Supported by Grainger CEME

Coupled Magnetics Applications of Ripple Correlation Control

Filters based on coupled inductors are promising for use in energy conversion applications, because they allow noisy waveforms to be "steered" into filter circuit elements. Our current work enhances coupled filters through an automatic tuning process that allows peaks or notches in filter characteristics to follow circuit characteristics such as switching frequency or specific noise frequencies. The result is a powerful stand-alone filter that has been verified both in simulation and in hardware. A paper on these techniques was presented at the 2002 Power Electronics Specialist Conference (PESC.) Future work involves applications of auto-tuning coupled inductor filters in a distributed DC power system.

Life Extension in Lead Acid Batteries

Although there have been numerous advances in battery technology recently, the lead acid battery continues to be the least cost option for energy storage in backup and remote energy applications. Often battery packs need to be replaced prematurely because of charge imbalances that occur when string connected. Previous work developed a charge equalization circuit that ensure uniform charge balance – preventing some cells from overcharging while other went undercharged. Data collected from recent charge / discharge cycling confirmed that our circuit was able to prolong the life of the battery pack. The equalizer technology also supports exchanging individual cells within the pack. A paper containing new results was presented at the 2002 International Telecommunications Energy Conference (INTLEC.)

Modular power electronics lab

Power electronics is a subject taught best by laboratory work in conjunction with formal lecture. However, the drawback is that considerable background is needed in the subject before even the simplest concepts can be demonstrated on the bench. A re-designed FET box consisting of two fully isolated FET devices and flexible controls was introduced into the instructional laboratory allowing numerous one and two switch topologies to be studied. A paper will be presented this summer at the 2003 Power Electronics Specialist Conference (PESC) highlighting our improvements in undergraduate power electronics instruction.

Jaesoo Byoun

Date of Birth:	June 16, 1972
Place of Birth:	Seoul, South Korea
B.S.:	October 1999, Soongsil University at Seoul, South Korea
M.S.:	August 2002, Purdue University
Ph.D.:	In progress
Professional Interests:	Power Electronics, Automatic Control, Low Power Electronics, Power IC, Microcontroller Architecture, Portable Power Management System, Phase and Delay Locking Loop Applications, PWM Generation and Analysis.

DLL-based Low-Power Multi-Input Multi-Output High-Frequency Digital-PWM PID Controller Architecture, IC Implementation and Applications

Jaesoo Byoun with advisor Prof. Patrick Chapman

Supported by Motorola Center for Communication and Grainger Center for Electric Machinery and Electromechanics

ABSTRACT

Digital-PWM is considered the next generation standard to convert, amplify and manage power signals. Digital-PWM is advantageous for low power consumption, immunity for analog noise, integrity with neighboring digital systems and implementation of complex control schemes. In both of academia and industry researchers are actively working on this, but most of them are expensive. This research work is distinguished by extremely low-power consumption due to using a DLL scheme, full integration of essential digital PID control loop, almost jitter-free DLL-based Digital-PWM generator scheme, half-area size multi-channel control and easy expendability for interface with neighboring systems. A versatile controller having these advantages is to be developed, fabricated, tested and analyzed for DC-DC power conversion.

Paola Caro-Ochoa

Date of Birth: August 8, 1976
Place of Birth: Santiago, Chile
B.S.: April 2000, Universidad de Chile
M.S.: In progress
Current Status:

Evaluation of Congestion Impacts in the Market Efficiency

Paola Caro-Ochoa with advisor George Gross

Supported by the Power Affiliates Program

ABSTRACT

Congestion in power systems has impacts on the operation of the system and on the economics of the markets. A way to quantify the economic impacts is in terms of the microeconomic metrics pertaining to social welfare, congestion rents, and surpluses (consumer and producer) of various players in the market. The loss of efficiency can be effectively captured through these metrics. This project focuses on the evaluation of congestion impacts in the market for nodal and zonal systems. A characterization of the loss of efficiency is presented, and the impact on this loss of efficiency due to changes in the supplier (producer) behaviors is examined, analytically and through simulations. Future work includes a characterization of the impact on the loss of efficiency due to changes in consumer behaviors; and developments of condition to aggregate buses in large-system so zonal studies can be implemented.

Xu Cheng

Date of Birth:	January 28, 1977
Place of Birth:	Yangzhou, P.R.China
B.S.:	July, 1999, Tsinghua University, Beijing, P.R.China
M.S.:	June, 2002, Tsinghua University, Beijing, P.R.China
PH.D:	In progress

Evaluating the potential for transmission constraints on the operation of a competitive electricity market in Illinois

Xu Cheng with advisor T.J. Overbye

Supported by Illinois Commerce Commission

ABSTRACT

The purpose of the study is to determine if the transmission system in Illinois and the surrounding region would be able to support a competitive electricity market, would allow for effective competition to keep prices in check, and would allow for new market participants to effectively compete for market share. The study will seek to determine if there are conditions that could reasonable be expected to occur that would enable a company to exercise market power in one or more portions of the state and thereby create undue pressure on the prices charged to customers and/inhibit new market participants from entering the market. The study will also identify where new market participants are potentially economically competitive but have limited ability co connect to load centers. It will determine what penalties are being paid, in the form of higher prices, for the inability to bring this power to where it can be used. The intent is to see if the limitations of the transmission system represent a substantial barrier to new market participants.

Philip Chorazy

Date of Birth:	April 27, 1978
Place of Birth:	Chicago, Illinois, U.S.A.
B.S.:	May 2000, Rose-Hulman Institute of Technology
M.S.:	August 2002

Visualization Techniques for Power System Analysis Software

Philip Chorazy with advisor T. J. Overbye

Supported by the Power Affiliates Program

ABSTRACT

This project is experimenting with visualization techniques for a power system analysis software package. The goal is to develop useful techniques for the operator of the power system such that power flow problems will be quickly recognized and corrected. Current work includes developing a Java interface and database for a web-based application of the power system analysis simulator. Then different visualization techniques will be implemented for use in human response testing for future work.

Pedro Correia

Date of Birth:	July 29, 1969
Place of Birth:	Lisbon, Portugal
B.S.:	July 1993, Instituto Superior Tecnico
M.S.:	May 1996, Instituto Superior Tecnico
Ph.D.:	May 2002
Professional Interests:	Power System Analysis; Competitive Electricity Markets; Power System Relaying

Strategic Equilibria in Centralized Electricity Markets

Pedro Correia with advisor T. J. Overbye

ABSTRACT

The emergence of competitive electricity markets has given rise to the problem of strategic bidding by market participants in the pursuit of profit maximization. Moreover, given the simultaneous action of all participants, the so-called Nash equilibria are the points in the bidding space that simultaneously satisfy the objective of all participants. The work focuses on the problem of finding multiple equilibria both in pure and in mixed strategies in an electricity market in which we assume that the market participants have reasonable estimates of other players' cost parameters. In addition, we assume that a central independent grid operator (IGO) dispatches the market using an OPF tool. We use the Individual Welfare Maximization, or IWM, that was previously developed for the purpose of finding a pure-strategy equilibrium and we further develop it for the multi-equilibria problem. This problem requires searching for solutions in the space regions defined by system constraints and, due to its exponential-size nature, we use specific problem reduction techniques.

Scott R. Dahman

Date of Birth:	September 13, 1971
Place of Birth:	St. Louis, MO USA
B.S.:	May 1993, Washington University
M.B.A	May 1994, Washington University
M.S.:	May 2003
Professional Interests:	Power System Economics, Demand Side Management

Demand Side Hedging of Risks Associated with Power Market Volatility

Scott R. Dahman with advisors T. J. Overbye and P. W. Sauer

Supported by Grainger Endowments

ABSTRACT

Spot market prices in restructured electricity markets are typically much more volatile than those of traditionally regulated markets, exposing power consumers to greater financial risk. Such risk may be mitigated through demand-side practices such as load leveling, two-sided auctions, long-term supply contracts, ownership of distributed generation, or financial hedging in options and futures contracts. This project specifically examines the ways that power consumers can reduce financial risk through hedging contracts. It reviews the principles of designing a financial hedging strategy, and then applies those principles to a specific environment of an industrial power consumer on an IEEE 30-bus network. Methods for expanding the solution to larger networks are also discussed.

Bryan Gary Dobbs

Date of Birth:	March 7, 1980
Place of Birth:	Schaumburg, IL
B.S.:	May 2002, Valparaiso University
M.S.:	December 2003, University of Illinois
Professional Interests:	Power Electronics, Power Systems, and Controls.

Multiple-Input DC-DC Converter Topologies

Bryan Dobbs with advisor Patrick L. Chapman

Supported by the National Science Foundation Grant ECS-01-34208
and Grainger Foundation

ABSTRACT

Current methods to convert multiple input power converters require building separate converters, and combining the controlled outputs. New topologies are explored which allow the conversion to be done with only one circuit. The new topologies are capable of interfacing sources of different voltage-current characteristics to a common load, while achieving a low part count. Fixed frequency switching strategies have been investigated and the resulting operating modes have been verified by experimentation. Real energy sources such as solar cell, and battery are used to show the flexibility of the topologies.

Vaibhav Donde

Date of Birth:	July 17, 1977
Place of Birth:	Thane (Maharashtra), India
B.S.:	June 1998, V. J. T. I., Mumbai, India
M.S.:	October 2000, University of Illinois at Urbana-Champaign
Ph.D.:	In progress, University of Illinois at Urbana-Champaign
Professional Interests:	Power systems, control systems.

Hybrid Dynamics and Oscillations in Electricity Supply Systems

Vaibhav Donde with advisors I. A. Hiskens and M. A. Pai

Supported by

ABSTRACT

Power systems have inherent interactions between continuous and discrete dynamical events. Devices such as tap changer, switched capacitors and circuit breakers induce discrete dynamics in power systems. In this work, behavior of such switched devices in a power system is studied. The research also looks into the stability analysis of hybrid dynamics in power systems, simulation of hybrid dynamics, border collision bifurcations and analysis of switched systems. Finally, optimal control methodologies are planned to be devised for switched-device related controls in power systems.

Michael Flowers

Date of Birth:	July 29, 1980
Place of Birth:	Midwest City, Oklahoma
B.S.:	May 2002, University of Colorado at Boulder
Professional Interests:	Power electronics, control systems and computer engineering.

Stator Design with Flex Circuit

Michael Flowers with advisor P. Krein

Supported by the Grainger Center

ABSTRACT

Stator construction currently consists of winding copper wire around steel teeth inside a metal jacket. Since the copper wire can be wound differently from one motor to the next, this method leads to non-repeatable results. There is also space lost between the wires (fill factor) because of the method used to wind the copper wires. This research analyzes the use of flex circuit as a substitute for winding the copper wire. Using flex circuit, one can 'print' wire turns on a board and then affix this board to a metal jacket. This leads to repeatable layouts and repeatable magnetic fields and allows greater flexibility when designing the wire distribution of the stator. In this research we examine different layouts of the flex circuit and the results of each.

Theresa Flowers

Date of Birth:	January 9, 1981
Place of Birth:	Fredericktown, Missouri
B.S.:	May 2002, University of Colorado at Boulder
M.S.:	December 2003, University of Illinois at Urbana-Champaign
Professional Interests:	Power electronics, control and alternative energy.

Low Voltage Input Boost Converter

Theresa Flowers with advisor P. L. Chapman

Supported by the Grainger Center for Electric Machinery and Electromechanics (CEME)

ABSTRACT

The purpose is to build a boost converter that has an input voltage lower than what is required to turn on a standard transistor (0.5V or less). A single fuel cell would produce such a voltage, so it is the target application

So far, the main focus has been to make a startup circuit that can switch the MOSFET a few times. This will produce an output voltage that is sufficient to sustain the circuit. So far we are working on two possible methods for initial switching. First, we are building a resonant circuit whose signal is stepped up using a transformer. This signal is then fed into the gate of the MOSFET, which will cause the switch to turn on and off, hence charging the output capacitor. The second method we are working on is using a mechanical switch to act as a one-cycle charge pump.

Xin Geng

Date of Birth:	October 20, 1977
Place of Birth:	Tianjin, P. R. China
B.S.:	July 2000, Tsinghua University, Beijing, P. R. China
M.S.:	October 2002, University of Illinois at Urbana-Champaign
Ph.D.:	In progress
Professional Interests:	Power Electronics, Control System, and Digital Signal Processing

Enhanced Digital PWM Control Schemes For Future Power Conversion Applications

Xin Geng with advisor P. T. Krein

Supported by the Grainger Center for Electric Machinery and Electromechanics and by the Motorola-UIUC Center for Communications

ABSTRACT

Pulse width modulation (PWM) has been widely used in power electronics to improve output waveform fidelity while achieving high efficiency. Conventional PWM process is constructed on an analog basis. However, there is a growing body of work on digital controllers for PWM converters due to their low power consumption, immunity to analog component variations, and ability to interface with digital systems and to implement sophisticated control schemes. The applications of digital PWM control schemes include microprocessor voltage regulation modules (VRM's), high-quality audio amplifiers, and portable electronic devices.

The objective of this project is to develop flexible digital controllers for various types of power converters, especially embedded converter systems; to explore a general programmable approach to provide flexibility for implementation. It is also desired to develop methods to achieve full range operation requirements such as multiple outputs power conversion, protection, start-up, regulation, and stability. The practical limitations when converting analog PWM process to a pure digital one are being studied. Issues like sampling, noise shaping, power supply noise rejection, and electromagnetic interference (EMI) are being explored in current work on the digital audio amplifiers.

Santiago Grijalva

Date of Birth:	November 25, 1970
Place of Birth:	Quito-Ecuador
B.S.:	1994, National Polytechnic University – Ecuador
M.S.	July 1997, Army Polytechnic University – Ecuador, Information Systems
M.S.:	August 1999, University of Illinois, Electrical Engineering
Ph.D.:	May 2002
Professional Interest:	Real-time control of power systems, power system economics, information systems.

Computation of Available Transfer Capability In Power Systems

Santiago Grijalva with advisor P. W. Sauer

Supported by Grainger Endowments

ABSTRACT

The project is investigating enhancements to current methods for computing Available Transfer Capability (ATC). New algorithms to incorporate the voltage effect in large transactions are studied. The work is focusing on power flow sensitivities, estimation of maximum loadability, linear/non-linear computation of ATC and boundaries of static load flow solution

Teoman Güler

Date of Birth:	November 14, 1976
Place of Birth:	Samsun, Turkey
B.S.:	July 1999, Bogazici University, Istanbul Turkey
M.S.:	May 2001, Rensselaer Polytechnic Institute
Ph.D.:	In progress
Professional Interests:	Power systems economics, energy derivatives.

Competitive Electricity Markets in the European Union

Teoman Guler with advisor Professor George Gross

ABSTRACT

The European Union issued the Electricity Directive 96/92/EC, with the objective to exploit the benefits of competition through liberalization of the electricity industry structure. We examined the main aspects of the EU restructuring. In addition, we analyzed some key issues for competitive electricity markets, including market power of suppliers, cross-border congestion, network access charges and unbundling. We also analyzed the role of these issues, as barriers to reach a fully competitive electricity market. Cross-border transmission capacities and their utilization gain crucial role in the re-structured electricity markets. The introduction of open access to transmission networks presented some key bottlenecks in cross-border transmission capacity. We examined several possible solutions to the cross-border transmission system capacity problems, such as effective cross-border capacity allocation, physical reinforcements and new cross-border transmission lines. We are also continuing to research the present situation on transmission network investments within the EU members that may increase cross-border transmission capacity. We also performed comparative analyses of European Union electricity market restructuring versus the restructuring in the US.

Nathaniel Hakes

Date of Birth:	October 12, 1978
Place of Birth:	Silvis, Illinois
B.S.:	December 2002, University of Illinois at Urbana-Champaign
M.S.:	In progress

Extended Factors for Linear Contingency Analysis

Nathaniel Hakes, with advisor P. W. Sauer

Supported by the Power Affiliates Program

ABSTRACT

This project is investigating new uses of linear methods for contingency analysis. Initial work is focusing on predicting the system impact when a line is removed and the effects on the system when the line is restored. This includes the estimation of torques on generator shafts.

Jean-Baptiste Heyberger

Date of Birth:	October 15, 1979
Place of Birth:	Saint-Germain en Laye, France
B.S.:	In progress (France)
M.S.:	In progress

Models of Transmission Lines in Transient Analysis

Jean-Baptiste Heyberger with advisor P. W. Sauer

Supported by the Power Affiliates Program

ABSTRACT

The Goal is to find a model for transmission lines in Transient analysis. Current work is focusing on attenuation of a phenomenon similar to the Gibbs Phenomenon when a lumped model is used with a large number of segments.

Barbara Ihrig

Date of Birth:	July 13, 1979
Place of Birth:	Stolberg/Rheinland, Germany
B.S.:	-
M.S.:	-
Current Status:	exchange student, working towards the 'Diploma'

Transmission congestion costs in the restructured electricity markets

Barbara Ihrig with advisor George Gross

Supported by the Power Affiliates Program

ABSTRACT

This project aims to quantify the impacts of congestion in the electricity markets in the restructured environment. Specifically, the actual prices in some of the ISOs, such as ISO-NE and CAISO, will be studied and assessed in terms of causality and impacts on price volatility.

Alexis Kwasinski

Date of Birth:	December 12, 1970
Place of Birth:	Buenos Aires, Argentina.
B.S:	February 1993, Buenos Aires Institute of Technology.
M.S.:	In progress
Research Interests:	Power Electronics, Electrical Energy Conversion and Storage.

Three Phase Inverter Control Techniques

One of the main aspects related with inverters is the different output waveform generation and control strategies. Two of the most important ones are "Sine Triangle Pulse Width Modulation" and "Space Vector Pulse Width Modulation" (SV-PWM). Although there are some studies relating both methods there has not been established yet in a clear and concise way the relationship between them. So, the first step of the analysis is to correlate clearly and in a direct way both control techniques. As a second step this relationship is used to develop better control techniques for selective harmonic elimination and other applications such as slow-sampling SV-PWM schemes. Finally, some 3-Dimentional schemes are also been used in order to represent the vector space and the control trajectories obtained which then are reflected as the output power signal. Ultimately the objective is to apply these techniques in the design of a three-phase inverter for motor drives. Usually the inverter design is done independently from the motor. However better performance and cost reduction can be achieved by integrating their design. In this sense, a 48Vdc input inverter is being studied which drives an induction motor without any major boost stages. Therefore, the specs of the motor needs to be defined in order to fit the relatively low voltage AC bus generated by the inverter.

Minghai Liu

Date of Birth:	January 7, 1974
Place of Birth:	Zhoushan, P. R. China
B.S.:	July 1997, Tsinghua University, Beijing, China
M.S.:	July 2000, Tsinghua University, Beijing, China
Ph.D.:	In progress
Professional Interests:	Power systems, Power economics.

Role of Congestion Revenue Rights in Competitive Electricity Markets

Minghai Liu with advisor George Gross

Supported by the National Science Foundation project 0000577 and PSERC and CERTS

ABSTRACT

The locational-marginal-price-based congestion management scheme exposes the transmission customers to the uncertain amount of congestion charges. Congestion revenue rights (CRR) are financial tools that provide price certainties on congestion charges. We study the characteristics of the CRR and explore their roles in the electricity markets by marrying certain aspects of the finance theory and nature of the electricity markets. Our current work including the construction of a mathematical framework for the analysis and design of the CRR and the exploration of the role and effectiveness of the distribution factors in the CRR applications.

Shanshan Liu

Date of Birth:	November, 1978
Place of Birth:	Jiangsu, China
B.S.:	July 2000, Tsinghua University
M.S.:	July 2002, Tsinghua University
Ph.D.:	In progress
Professional Interests:	Power systems, machinery, and control.

Variable Frequency Transformers for Power Flow Control

Shanshan Liu with advisor P. W. Sauer

Supported by the Grainger Foundation

ABSTRACT

Variable Frequency Transformers utilize an old concept of doubly-fed induction machines. At zero speed, they are simple phase-shifting transformers whose power transfer is determined by rotor position control. For asynchronous operation, the rotor speed allows smooth transfer of power between systems of different frequencies - thus the name Variable Frequency Transformer. This feature provides an opportunity to help power systems recover from faults, which would otherwise cause loss of synchronism. This project is investigating the control capabilities of these devices for potential use in system stabilization.

Henry Louie

Date of Birth:	October 18, 1979
Place of Birth:	Ft. Lewis, Washington
B.S.:	June 2002, Kettering University (Formerly GMI)
M.S.:	In progress
Professional Interests:	Power systems analysis, Power system protection

Line Closure Impacts on Generator Dynamics

Henry Louie with advisor P.W. Sauer

Supported by the Grainger Foundation

ABSTRACT

The opening of a line breaker can result in a difference in phase angle across the breaker's poles. The closure of the breaker, under these conditions, causes the network currents to redistribute and could possibly induce damaging torques in the system generators. To mitigate this occurrence, the generation can be dispatched in a way such that the angle across the breaker is within a specified tolerance before breaker closure. This research studies the effects of breaker closure under large angle differences on the transient generator currents and dynamics. A complete understanding of these consequences will allow engineers to evaluate breaker angle closure tolerances with a higher degree of accuracy and possibly avoid unnecessary system changes.

Joseph Mossoba

Date of Birth:	May 12, 1977
Place of Birth:	Washington, D.C. (U.S. Citizen)
B.S.:	University of Toronto - 1999
M.S.:	University of Toronto - 2002
Current Status:	Ph.D. qualifying candidate (2002)
Professional Interests:	Modeling and control of power electronics.

Nonlinear Analysis and Control of dc-dc Converters

Joseph T. Mossoba with advisor Prof. Phil T. Krein

Supported by the Power Affiliates Program

ABSTRACT

Nonlinear systems such as switching dc-dc converters are often linearized for small signal analysis and linear controller design. Certain types of nonlinear control, especially the popular current-mode control method, can be analyzed as an additional linear feedback control loop. Current feedback, implemented through current-mode control, improves the performance of dc-dc converters in many applications. In this project, we are considering sensorless current-mode control (SCM), an alternative approach that uses estimators in place of a sensed current signal. This approach provides a feedforward effect in a dc-dc converter, and offers most of the performance advantages of current-mode control without the limits of a current sensor. However, design methodologies for SCM have not been fully developed. A small signal model of SCM is developed in this project. Initial goals of this work include simulation and experimental tests to validate the SCM model. The model will then be used to create a design framework for this control method. The long-term objective is to derive large-signal models suitable for the design of nonlinear dc-dc converter controllers.

Oscar F. Muñoz

Date of Birth:	October 16, 1975
Place of Birth:	Mexico, D.F., Mexico
B.S.:	February 1998, Instituto Politécnico Nacional
M.S.:	August 2002
Professional Interests:	Power systems operation and control, utility restructuring, computational algorithms.

Market Power Analysis of Electric Power Systems

Supported by Fulbright Fellowship

ABSTRACT

The goal of this project is to determine the amount of potential market power in bulk electricity markets, with the explicit consideration of the transmission system. In general, market power is the ability of a particular seller or group of sellers to maintain prices profitably above competitive levels for a significant period of time. The restructuring of the electric industry has encouraged competitive markets with the objective of reaping the benefits of lower prices and innovation that competition can provide. Such benefits are not attainable when a player utilizing the electric transmission system may exercise such market power.

Surya Musunuri

Date of Birth:	March 21, 1980
Place of Birth:	Machilipatnam, Andhra Pradesh, India
B.Tech.:	June-2001, Jawaharlal Nehru Technological University, Hyderabad, India
M.S.:	In progess
Professional Interests:	Power Electronics, Integrated Circuits, and High-speed analog circuits.

Fully-Integrated CMOS DC-DC Converters

Department of Electrical and Computer Engineering
University of Illinois, Urbana-Champaign

Abstract

With the reduction of power consumption in most of the portable and consumer electronics, *on-chip* DC-DC converters promise better performance than the off-chip converters. Our previous work studied various ideas for integrating different components of DC-DC converter in to a silicon chip. It also dealt with the optimization of chip area taken by these components. An optimal layout for a DC-DC boost and buck converter was designed based on these area optimizations and corresponding trade-offs.

The results from the fabricated chips, designed based on above optimization, show that the spiral inductor fails to perform in a boost converter while working better for the buck converter configuration. The MEMS (micro electromechanical systems) inductor is the best alternative for boost converter as it provides better energy storage capacity. The output of the buck converter is along the expected lines with the spiral inductor. Thus, an on-chip DC/DC buck converter was achieved using a spiral inductor and a boost converter was achieved using MEMS inductor. The results from the fabricated chips meet the specifications, indicating the validity of the optimization and design for the frequency range of 1-10MHz.

Tony Nguyen

Date of Birth:	September 10, 1966
Place of Birth:	Vietnam
B.S.:	January 1998, University of Illinois
M.S.:	August 1999, University of Illinois
Ph.D.:	August 2002
Professional Interests:	Power system stability, control, and computation.

Dynamic ATC Computations Using Sensitivity Functions

Tony Nguyen with advisors M. A. Pai and I. H. Hiskens

Supported by the National Science Foundation

ABSTRACT

In this research we wish to investigate the use of trajectory sensitivities as a tool to compute dynamic available transfer capabilities (ATC) in a power system. Currently, transient energy function (TEF) method is being proposed but its major drawback is the need to compute the controlling unstable equilibrium point (u.e.p.) to obtain the critical energy. However, the TEF is a very useful concept and can be used as a metric in computing an estimate of t_{cr} without computing the u.e.p. Initial results are very encouraging. The sensitivity approach is independent of modeling complexity. Sensitivity of power transfer over tie lines with respect to generation for a set of contingencies gives useful information regarding rescheduling of generation if found necessary. This concept has been successfully tested on a 10-machine, 39-bus system. The idea can be extended to compute dynamic ATC.

Penglin Niu

Date of Birth:	February 19, 1979
Place of Birth:	Xi'an, China
B.S.:	July 2001, Shanghai Jiao Tong University, China
M.S.:	May 2003, University of Missouri-Rolla
Ph.D.:	2006(expected), University of Illinois at Urbana-Champaign
Professional Interests:	Electric Machine, Power Electronics, and Power System.

Biomechanical Energy Conversion Technology

Penglin Niu with advisor Patrick L. Chapman

Supported by the Office of Navy Research

ABSTRACT

Traditionally, mobile electronic devices have the problem of changing batteries or recharging batteries often. This is sometimes troublesome, especially for military field operations. One possible solution is to convert the wasted biomechanical energy, the human body movement energy to the useful electrical energy for the electronic devices. This will require both high efficiency and low physical influence on the human movement. In this research, we will analyze appropriate means of electromechanical energy conversion, find the best devices for the conversion of various type of human movement energy, and develop circuit designs to match to new electromechanical devices. Finally we will realize the hardware of the devices and its matching circuit.

James Owens

Date of Birth:	November 2, 1979
Place of Birth:	Oak Lawn, Illinois
B.S.:	May 2002, University of Illinois at Chicago

Reduced Finite Element Analysis for Magnetic Devices

James Owens with advisor P. L. Chapman

Supported by the Power Affiliates Program

ABSTRACT

Finite element analysis is an important tool in the modeling of the magnetic field characteristics of induction machines. It can be especially beneficial when combined with model order reduction techniques. In this paper, the goal is to reduce the number of state variables in the finite element method producing a more compact input to the model order reduction technique.

Sheila Ray

Date of Birth:	August 1, 1980
Place of Birth:	Birmingham, AL
B.S.:	May 2002, University of Illinois at Urbana-Champaign
M.S.:	In progress
Professional Interests:	Power systems, Alternative Energy Sources, Control Systems

Generator Shaft Torques During Transients

Sheila Ray with advisor P.W. Sauer

Supported by the Grainger Foundation

ABSTRACT

Through the simulation of power systems, the effects of transients can be determined. Specifically, the generator shaft torque can be examined. In order to investigate the effects of faults, line outages, and line reclosings, simulation of various power system dynamics is performed with a power system simulator, PSS/E, from PTI Technologies, Inc. For the simulation, accurate models of the generators, transmission lines, buses and loads are created.

Pablo Ariel Ruiz

Date of Birth:	August 4, 1978
Place of Birth:	Santa Fe, Argentina
B.S.:	July 2002, Universidad Tecnológica Nacional, Facultad Regional Santa Fe
M.S.:	In progress
Professional Interests:	Power Systems Economics.

Resource Adequacy and Capacity Markets in NYISO and ISO-NE

Pablo Ariel Ruiz with advisor George Gross

Supported by the Power Affiliates Program

ABSTRACT

This project aims to develop a mathematical framework for evaluating the results of the capacity markets in NYISO and ISO-NE. It has been argued that the purpose of the capacity markets is to ensure an adequate amount of resources in the region to meet the load with a predefined loss of load expectation, and to diminish the volatility of the prices in the energy markets. The current work focuses on the description of the interaction between the capacity markets and the energy and reserve markets in NYISO and ISO-NE. Future work includes the development of different approaches to ensure resource adequacy and their comparison with the current capacity markets.

Vilma Sierra

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Place of Birth:	Tegucigalpa, Honduras
B.S.	Universidad Nacional Autonoma de Honduras, 1994,
M.B.A.	Universidad Nacional Autonoma de Honduras, 1999
M. S:	Currently enrolled in MS Program, expected degree in 2004.

Transmission Congestion Cost in the Restructured Electricity Market with Emphasis in New York Market

Vilma Sierra with advisor George Gross

ABSTRACT

This project aims to identify the way congestion is measured in the restructured environment in the New York ISO market. Congestion is a problem of major impact on the economics of electricity markets and in NY it is of high importance due to the large costs associated with congestion impacts. The main effort will lie in the analysis of congestion data; congestion quantities and costs will be analyzed in detail and examined to establish possible patterns. The effects of mitigation of the NYISO's Transmission Congestion Contracts will be evaluated.

Zakdy Sorchini

Date of Birth:	August 11, 1977
Place of Birth:	Mexico City, Mexico
B.S.:	December 2000, Instituto Tecnológico y de Estudios Superiores de Monterrey, Monterrey, Mexico
M.S.:	In progress

Power Line Proximity Estimation

Zakdy Sorchini with advisor Philip T. Krein

Supported by the Power Affiliates Program

ABSTRACT

This project deals with estimating the proximity to a power line in a construction environment. Since the safety level is linked with the power line's voltage, a capacitive sensor that relies on the voltage induced by the electric field was used. The sensor also provides electric field gradient information, which was found to be useful for proximity estimation. Finite element method analysis aided in sensor design and performance evaluation via simulations. Laboratory and field experiments were done to corroborate the behavior predicted by simulation and to evaluate system performance. Finally, a decision law that correlates information obtained by the sensor with safety was explored and proposed.

Yan Sun

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Place of Birth:	Songyuan, Jilin Province, P. R. China
B.S.:	1997, Tsinghua University, Beijing, P. R. CHINA
M.S:	2000, Tsinghua University, Beijing, P. R. CHINA
Ph.D.:	In progress
Professional Interests:	Power System Simulation and Electricity Markets

Electric Power System Visualization

Yan Sun with advisor T. J. Overbye

Supported by Grainger Foundation and PSERC

ABSTRACT

As the electricity industry becomes increasingly competitive, knowledge concerning the capacity and constraints of the electric system will become a commodity of great value. Electricity markets can be fast changing; understanding the implications of these changes before others can give an important competitive advantage. The goal of this project is to develop innovative methods to assist players in the electricity industry to extract and visualize this knowledge from the large set of power system data. The project is exploring the use of techniques for knowledge extraction utilizing two-dimensional displays, as well as the use of an interactive three-dimensional environment.

Worapot Tangmunarunkit

Date of Birth:	December 19, 1976
Place of Birth:	Muang, Yala, Thailand
B.S.:	May 2000, University of Wisconsin at Madison
M.S.:	In progress
Professional Interests:	Power System, Control system.

Optimal Load Shedding Against Voltage Instability

Worapot Tangmunarunkit with advisor I. H. Hiskens

Supported by Grainger Foundation and National Science Foundation (NSF)

ABSTRACT

With the limiting factors of the transmission system, it is common that the voltage of the system will be unstable when some disturbances have been introduced. Load shedding provides an effective (though drastic) control strategy for alleviating voltage instability when such a server disturbance is introduced to the system. Load shedding, however, should be implemented in an optimal way in order to satisfy most customers. Therefore, it is important to establish a systematic way to determine amount of shed loads and shedding delays that will minimize the cost of the lost load. Since the behavior of power system involves complex interaction between continuous dynamics and events of discrete nature, hybrid model is to be used to capture the system behavior. With the different orders of the events and parameters in hybrid system, the optimization problems might take on a combinatorial nature. The local minimum of each continuous section of cost function needs to be searched in order to find the global optimization.

Wayne Weaver

Date of Birth:	March 28, 1974
Place of Birth:	Albion, Michigan
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Professional Interests:	Power systems, Power Electronics.

Implementation Techniques for Flexible Power Systems

Wayne Weaver with advisor P.T. Krein

Supported by National Science Foundation Grant NSF ECS-0224829

ABSTRACT

Flexible power systems require fast reconfiguration, comprehensive sensing, and extremely high reliability. Modern power electronics provides tools to achieve these requirements. One technique is dynamic buffering which takes advantage of the need for power conversion for many types of loads. Through the power conversion process energy is also stored and used to mitigate the affects of system disturbances and instabilities. Over short time intervals this stored energy can be used to dynamically decouple the load from the power system during transients. This can avoid instability problems caused by constant-power load characteristics. It also permits the energy storage to be distributed throughout the system. Each buffer can be set to make use of local energy storage to ride through a short-term failure or to shut down gracefully in the event of a long-term outage. In this research we will examine the application of various dynamic buffer techniques and their affects on delivering clean power to the load during power system transients with durations that rage over several orders of magnitude in time. In addition we will examine dynamic buffer techniques that will seek to actively stabilize a disturbed system.

Jason Wells

Date of Birth:	October 7, 1978
Place of Birth:	Cherry Valley, Illinois
B.S.:	May 2000, University of Illinois
M.S.:	Dec 2002, University of Illinois
PhD:	In Progress
Professional Interests:	Electric machinery, Electric Drives, Power Electronics

Application of Ripple Correlation Control to Electric Machinery

Jason Wells with advisor P. L. Chapman

Grainger Center for Electric Machinery and Electromechanics

ABSTRACT

The goal of this project is to apply ripple correlation control to a variety of optimization problems in electric machinery. The control uses the perturbation of the system generated by the ripple of the dc rectifier to correlate the flux magnitude to the efficiency of the machine. Ultimately, the flux controller can be used to track the optimal flux for highest efficiency over the load range and reduce losses caused by an over-excited machine.

Future Energy Challenge: Innovations in Motor Drives and Motor Drive Systems

Jason Wells with advisor P. L. Chapman and P. T. Krein

Grainger Center for Electric Machinery and Electromechanics

ABSTRACT

The 2003 Future Energy Challenge (FEC) is a multi-disciplinary international competition focused on making dramatic advances in the way energy is consumed in the home. The University of Illinois has committed to compete under the topic of single phase motors and drives. The goals set forth by the competition announcement are to design and build a prototype motor and drive system that meets the primary specifications summarized in the list below.

- Deliver rated shaft load of 500 W at 1500 RPM
- Exhibit useful speed control range of at least 150 RPM to 5000 RPM
- Provide power efficiency of at least 70% for loads ranging from 50 W to 500 W at a specified speed within the operating range
- Maintain a unit mass production cost below $ 40.00

To achieve the specified criteria, the University of Illinois FEC team proposes a complete and integrated design of the motor and drive system. Traditionally, standard motor designs, which have been optimized for 60 Hz operation, are chosen and then drive circuitry has been designed around the motor. This practice does not make sense if the motor will be used in a variable speed application with an electronic drive capable of providing a wide range of input frequencies. By integrating the design of the motor and the inverter, we can achieve significant cost savings and performance increases in both components.

Alan Wu

Date of Birth:	08/04/1980
Place of Birth:	Chicago, IL
B.S.:	BSEE University of Illinois (Urbana/Champaign)
M.S.:	In progress
Current Status:	Research Assistant for Prof. Chapman

Constant Torque for PM Synchronous Motors

Alan Wu with advisor Patrick Chapman

Supported by the Power Affiliates Program

ABSTRACT

Our work deals with current waveform shaping for permanent magnet synchronous machines (PMSM), for reduced torque ripple, increased efficiency, and minimal additional costs. A method was developed such that given the back emf waveforms of a PMSM, the desired current waveforms would be obtained such that, one can theoretically eliminate the torque ripples inherent with conventional PMSM drives, and minimize rms current flow. Measurements obtained reveals that up to a 2% torque ripple may appear in a high-end sinusoidal drives, due to asymmetrical and unbalanced stator windings alone. This ripple is comparable to the cogging torque ripple that is the subject of many other works.

Rodney Yeu

Date of Birth:	December 16, 1979
Place of Birth:	Seoul, Korea
B.S.:	December 2002, University of Illinois, Urbana-Champaign
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Professional Interests:	Power systems, power electronics and control engineering

Real-Time Fault Current Analysis

Rodney Yeu with advisor P. Sauer

Supported by the Grainger Foundation Endorsements

ABSTRACT

When a fault occurs, it can cause instability and equipment damage in a power system. It is important to know the potential fault current values in real time. The goal of this work is to predict the potential fault currents using normal SCADA measurements of real-time conditions.

Guoliang Zhang

Date of Birth:	November 05, 1977
Place of Birth:	Beijing, China
B.S.:	June 2000, Tsinghua University
M.S.:	May 2002, Gannon University
Ph.D. (expected):	Jan 2007, University of Illinois at Urbana-Champaign
Professional Interests:	Electric motor and drive systems, automatic control.

Parameter/Measurement Sensitivity Analysis in Vector Controlled Induction Machine

Guoliang Zhang with advisor P.T. Krein

Supported by Grainger Foundation

ABSTRACT

The project is to carry out analysis of the vector controlled induction machine performance degrading due to parameter sensitivity and the measurement inaccuracy. Try to find the mathematical model of such degrading, hence to find ways to correct/compensate parameter change/measurement inaccuracy and achieve more robust vector control over the induction motor. Run simulations to demonstrate/verify the mathematical model and predict the performance of the modified vector control algorithm.

At this stage, the detailed induction motor and the indirect field-oriented vector cotontroller have been modeled in Matlab/Simulink. Some simulations have been performed.

Adam J. Zook

Date of Birth:	March 6, 1980
Place of Birth:	Joliet, Illinois
B.S.:	May 2002, University of Illinois, Urbana-Champaign
M.S.:	In progress
Professional Interests:	Power systems, distributed generation.

Effects of Distributed Generation on System Stability

Adam Zook with advisor M. A. Pai

ABSTRACT

The addition of distributed generation to existing transmission systems is often regarded as detrimental to system stability. Through a series of simulations, we will examine the effects of distributed generation at multiple penetration levels and geographic locations. By this, we will gain a better understanding of distributed generation's effects so that future DG projects will be able to choose the best addition to the transmission system.

8. LABORATORY FACILITIES

The Power Area has assembled some of the nation's finest facilities for experimental and computer-based research and teaching. Both undergraduate and graduate students can take advantage of these facilities. These laboratories have generated wide interest.

The **Grainger Power Engineering Software Laboratory** is located near the office areas on the third floor of Everitt Laboratory. The Laboratory has ten advanced personal computers and workstations. All stations are connected to the campus network and Internet.

A major objective of the laboratory is to develop an extensive library of commercial software and large-scale databases for power area applications. Software is based on the Linux operating system and on Windows 2000. Some of the commercial software packages currently in use include:

Mathematica (an advanced symbolic mathematics package)
SYMNON (system analysis and design software)
IPFLOW (Interactive Power Flow)
SSSP (Small Signal Stability Analysis)
MatLab and Simulink
PSS/E (Power Technologies Inc. Software Package)
PowerWorld
Power System Tool Box (PST Version 2.0)

The software library is being expanded continually.

The **Grainger Electrical Machinery Laboratory** is located on the ground floor of Everitt Laboratory. This facility is primarily for undergraduate teaching, and is used for ECE 333, ECE 369, many ECE 345 projects, and the Advanced Electric Vehicle Program. Ten self-contained machinery workstations are available. Each has an integral horsepower machine set, digital wattmeters, oscilloscope, optical tachometer, torque sensor, and electronic support instruments. Transformers, resistor units, capacitors, SCR circuits, small electronic and power FET units are provided in support of the full range of experiments in all aspects of power. The facility has a dedicated 225 KVA three-phase supply and a 50 kW d-c rectifier bank.

The **Advanced Power Applications Laboratory** is adjacent to the Grainger Electrical Machinery Laboratory. This laboratory serves as a general research facility for all hardware aspects of power electronics, machines, and power systems. The lab shares motor test sets with the Machinery Lab. Additional equipment is available for the study of harmonic effects, high-performance switching converters, and digitally controlled drives. This laboratory's computer facilities communicate with the Grainger Power Engineering Software Laboratory through the Internet.

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